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September 1995

Monongahela Dam 2 Spillway, Monongahela River, Pennsylvania

by Deborah R. Cooper

Prepared for U.S. Army Engineer District, Pittsburgh

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U.S. Army Corps of Engineers
Waterways Experiment Station
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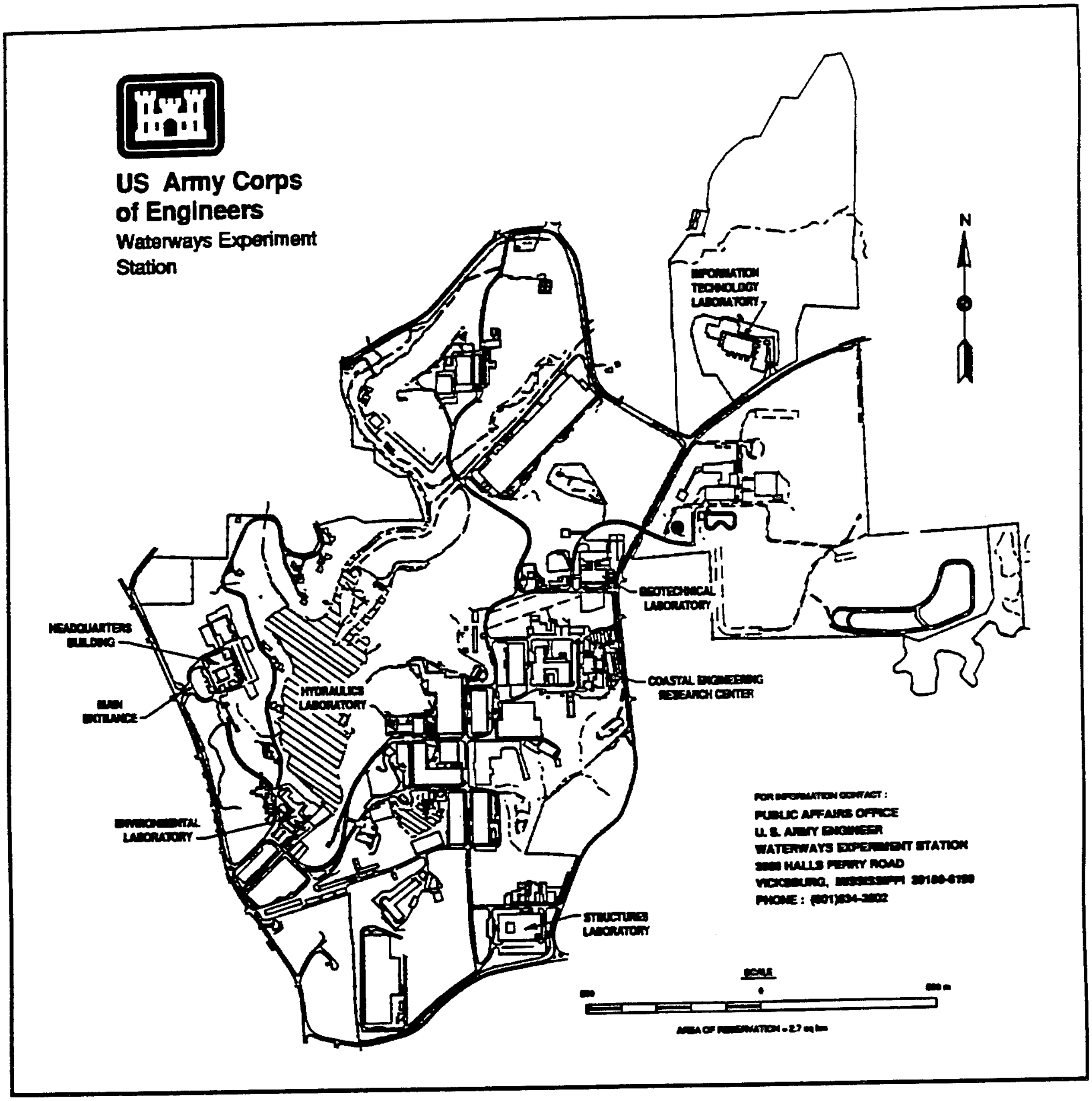

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Preface

The investigation reported herein was authorized by Headquarters, U.S. Army Corps of Engineers, on 18 April 1991 at the request of the U.S. Army Engineer District, Pittsburgh.

The studies were conducted in the Hydraulics Laboratory (HL) of the U.S. Army Engineer Waterways Experiment Station (WES) during the period April 1992 to September 1994 under the direction of Messrs. F. A. Herrmann, Jr., Director, HL; R. A. Sager, Assistant Director, HL; and G. A. Pickering, Chief, Hydraulic Structures Division (HSD), HL. The tests were conducted by Mrs. D. R. Cooper, Mr. R. Bryant, Jr., and Mr. E. L. Jefferson of the Spillways and Channels Branch, HSD, under the direct supervision of Mr. N. R. Oswalt, Chief of the Spillways and Channels Branch. This report was prepared by Mrs. Cooper.

During the course of the investigation Messrs. W. Leput and R. Povirk of the Pittsburgh District visited WES to discuss test results and correlate these results with current design studies. On 24-25 March 1994, the model was viewed by representatives from the Pittsburgh District, the U.S. Army Engineer Division, Ohio River, and the navigation industry.

Mr. Melvin Bolden, Engineering and Construction Services Division, WES, constructed the spillway, gates, and lock wall.

During publication of this report, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
feet	0.3048	meters
inches	25.4	millimeters
miles (U.S. statute)	1.609347	kilometres
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter

1 Introduction

The Prototype

This report describes model tests and results for a section of the Monongahela Dam 2 spillway project. Monongahela Dam 2 is located on the Monongahela River 11.2 miles[1] upstream of the confluence of the Ohio, Allegheny, and Monongahela Rivers, in the city of North Braddock, PA (Figure 1). The existing dam maintains the 12.6-mile-long navigation pool between the Dam 2 and Dam 3 locks and dams (L&D). Normal upper pool elevation for Monongahela 2 is presently at el 718.7.[2] The minimum tailwater is at el 710.0.

The existing spillway section of Dam 2 consists of a fixed crest (el 718.7) located within the main channel of the waterway. Energy is dissipated on a horizontal apron with baffle blocks terminated by an end sill. The U.S. Army Engineer District, Pittsburgh, developed a "two-for-three" plan for renovating locks and dams on the lower Monongahela River that would save the cost of having to reconstruct L&D 3 and reduce transportation costs by eliminating bottlenecks caused by the small locks at L&D's 3 and 4 and by reducing one lockage cycle. The plan calls for building a new gated dam at the current L&D 2, eliminating L&D 3, and replacing the locks at L&D 4 with new, larger locks. The change would also mean Pool 2 would be raised by about 5 ft, and the current Pool 3 would be lowered by about 3 ft.

The dam now proposed for the L&D 2 site will consist of a navigable gated structure with three low sills (crest el 704.7), a water quality sill (crest el 714.0), and a fixed-crest weir (crest el 723.7) as shown in Plates 1-4.

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1 A table of factors for converting non-SI units of measurement to SI units of measurement is presented on page vi.

2 All elevations (el) and stages cited herein are in feet referred to the National Geodetic Vertical Datum (NGVD).

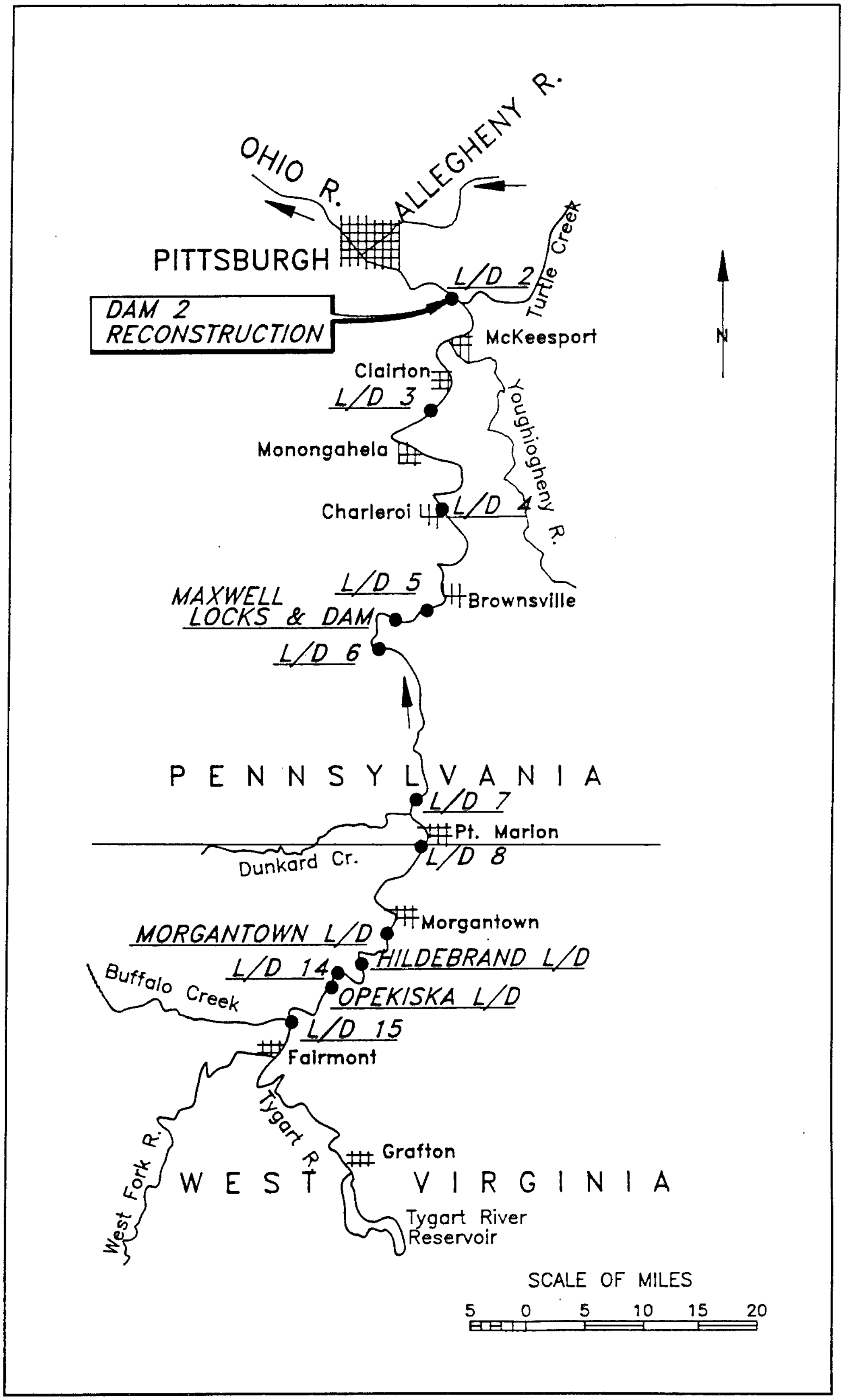


Figure 1. Monongahela River

Purpose and Scope of the Model Study

The spillway sectional model was conducted to investigate the hydraulic performance to be expected with the low sills and water quality sill under long-range operating conditions for controlled and uncontrolled flows. Specifically, the model study would provide the data necessary to evaluate and develop a satisfactory means of regulating the structure to achieve the desired flow objectives without creating adverse hydraulic conditions. The following information was obtained for the low- and high-gate bays:

a. Flow characteristics and stilling basin performance with gates fully open (uncontrolled flow).

b. Flow characteristics and stilling basin performance with partial closure of the gates from the top of the structure (orifice flow under gates).

c. Relative degree of turbulence (as shown by dye) observed visually in the stilling basin and exit channel.

d. Riprap requirements for protection upstream and downstream of the structure and passage of ice.

e. Discharge characteristics and coefficients with various operating scenarios.

Presentation of Data

In the presentation of test results, no attempt is made to introduce the data in the chronological order in which the tests were conducted on the model. Instead, as each element of the structure is considered, all tests conducted thereon are discussed in detail. All model data are presented in terms of prototype equivalents. All tests are discussed in Part 3 of this report.

2 The Model and Test Procedure

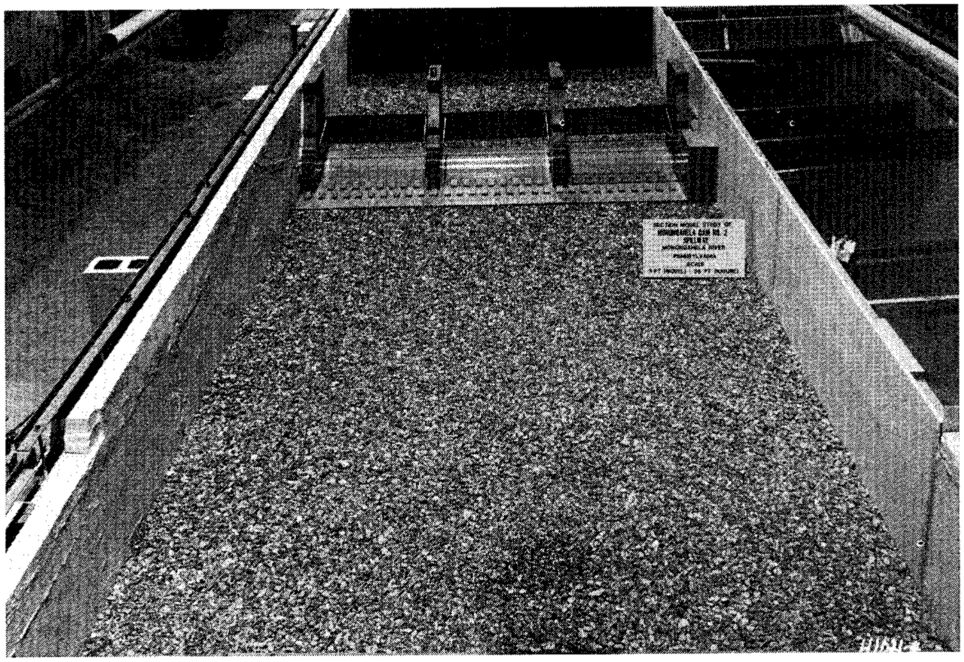
Description

Originally the 1:36-scale section model (Figure 2, Plates 5 and 6) reproduced a 396-ft-wide section of the dam consisting of three broad-crested sills at el 696.7, three 110-ft-wide and 29-ft-high tainter gates, four piers and the left abutment, an 85-ft-long stilling basin and basin elements, 250 ft of the upstream approach channel, and 500 ft of the exit channel. The spillway section, piers, and tainter gates were constructed of metal, and the stilling basin and basin elements were constructed of plywood. The portions of the model representing the approach and exit channels were molded in sand and gravel. The original design is referred to as configuration 1.

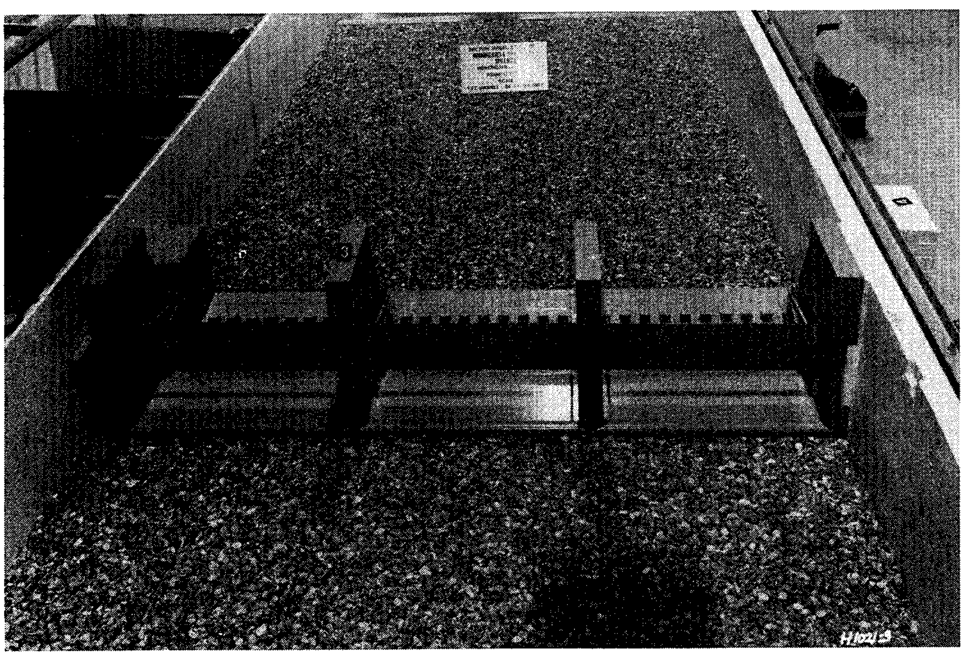
To examine the discharge characteristics and riprap requirements for another section of the dam, the section model was modified (configuration 2) to reproduce a 396-ft-wide section of the dam consisting of one broad-crested low sill at el 696.7, one water quality sill at el 714.0, a fixed-crest weir at el 723.7, one 110-ft-wide and 29-ft-high tainter gate, one 110-ft-wide and 11.7-ft-high tainter gate, four piers and the lock wall, an 85-ft-long stilling basin and basin elements, 250 ft of the upstream approach channel, and 500 ft of the exit channel (Figure 3, Plates 7 and 8).

The Pittsburgh District redesigned the dam, raising the sills 8 ft and eliminating one gate bay, a change that produced considerable cost savings while providing satisfactory discharge capability.

To examine the discharge characteristics and riprap requirements for the 8-ft raise, the model was modified to reproduce a 396-ft-wide section of the dam consisting of three broad-crested low sills at el 704.7, three 110-ft-wide and 21-ft-high tainter gates, a 79.5-ft-long stilling basin and basin elements, 250 ft of the upstream approach channel, and 500 ft of the exit channel (Figure 4, Plates 1 and 2). This design is referred to as configuration 3.

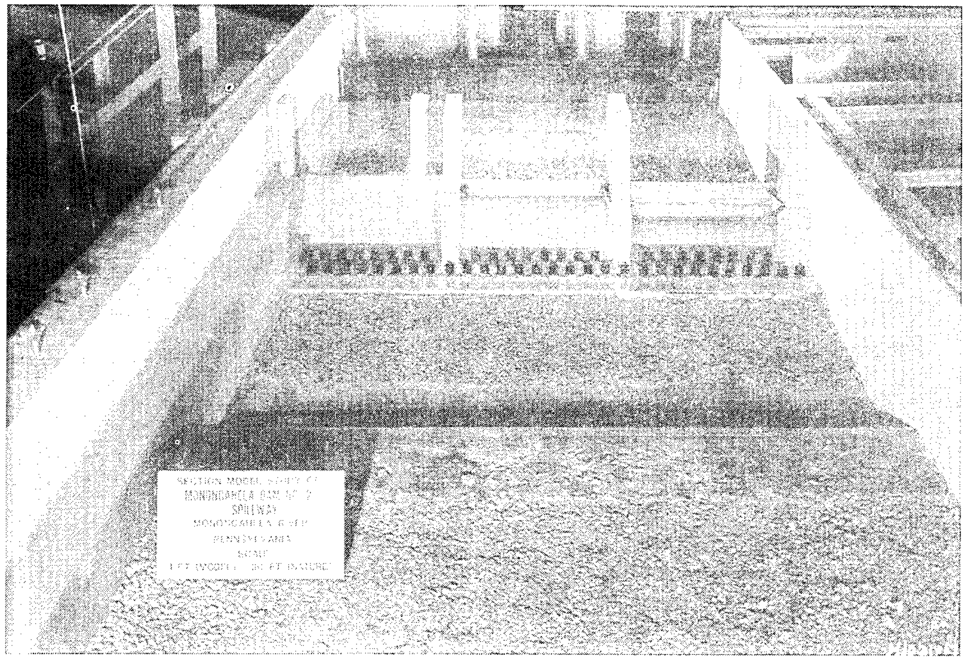


a. Looking upstream

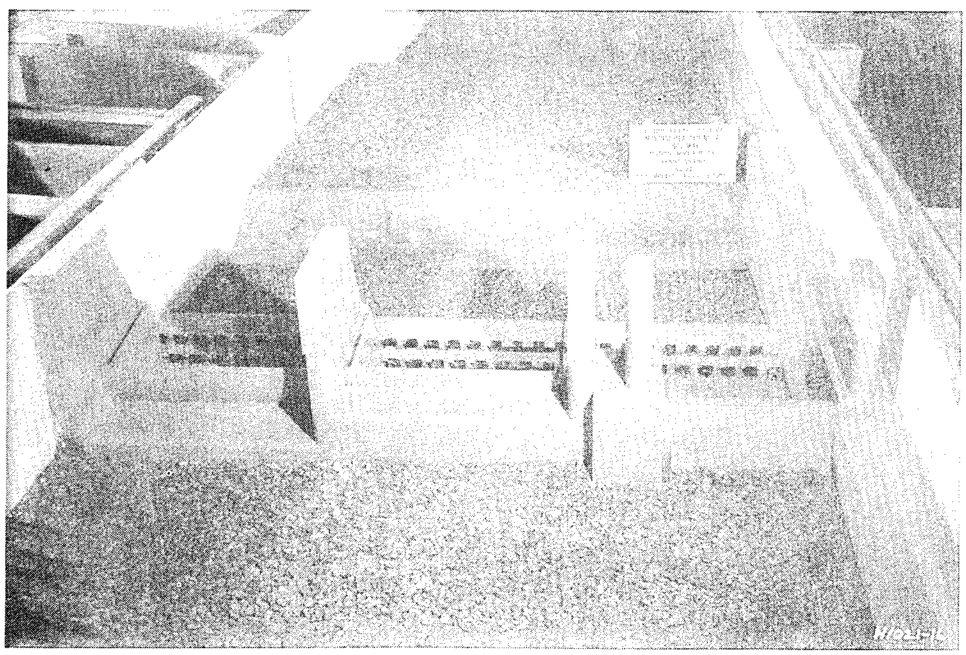


b. Looking downstream

Figure 2. Configuration 1



a. Looking upstream



b. Looking downstream

Figure 3. Configuration 2

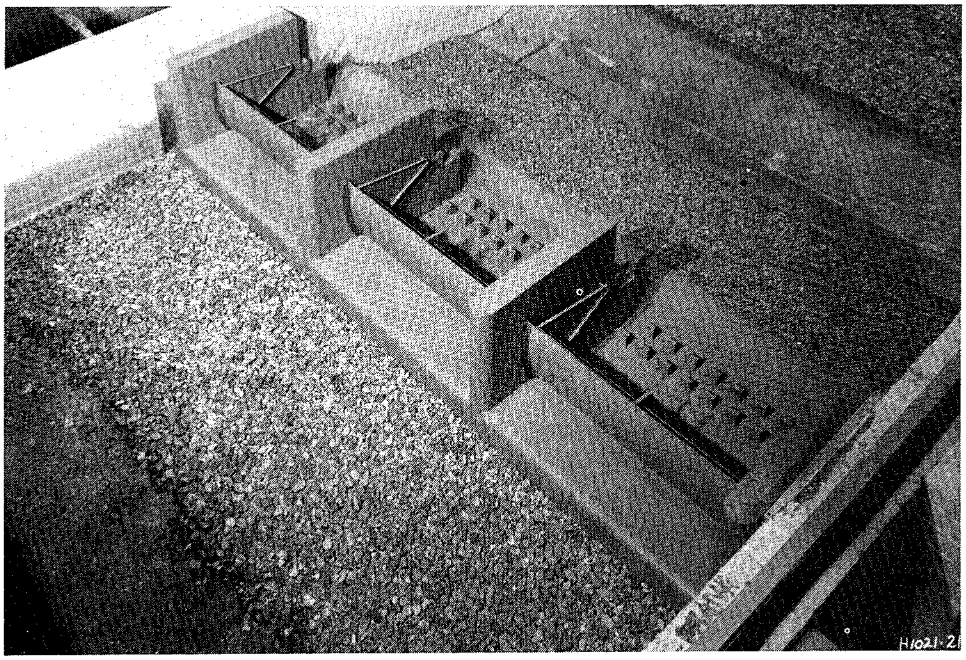


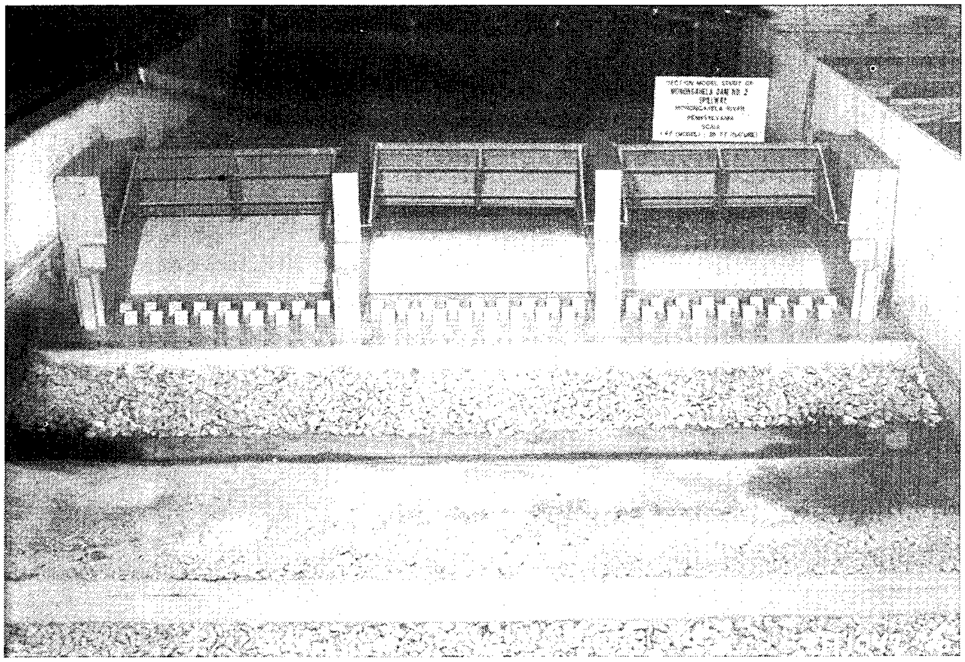
Figure 4. Configuration 3 looking downstream

To examine the discharge characteristics and riprap requirements for another section of the dam, the section model was modified to reproduce a 396-ft-wide section of the dam consisting of one broad-crested low sill at el 704.7, one water quality sill at el 714.0, a fixed-crest weir at el 723.7, one 110-ft-wide and 21-ft-high tainter gate, one 110-ft-wide and 11.7-ft-high tainter gate, four piers, a 79.5-ft-long stilling basin and basin elements, 250 ft of the upstream approach channel, and 500 ft of the exit channel (Figure 5, Plates 3 and 4). This design is referred to as configuration 4.

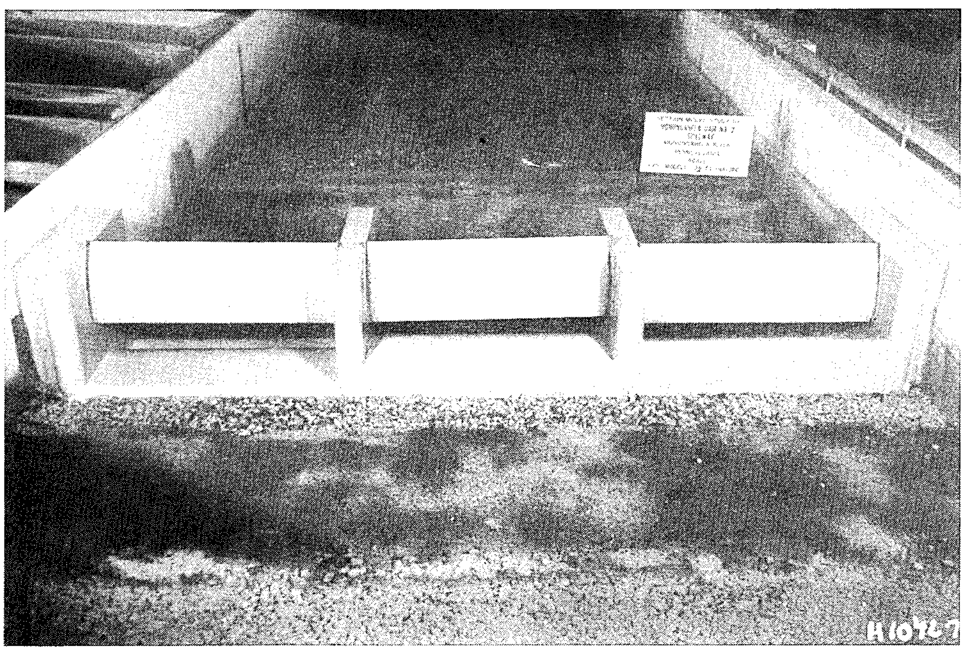
The weir section, piers, and tainter gates were constructed of metal. The stilling basin and basin elements were constructed of wood. The portions of the model representing the approach channel were molded in pea gravel and dusted with cement, and the exit channel was molded in sand and gravel.

Appurtenances and Instrumentation

Water used in the operation of the model was supplied by pumps, and discharges were measured with venturi meters. The tailwater in the downstream end of the model was controlled by an adjustable tailgate. Steel rails set to grade provided reference planes. Water-surface elevations were obtained with point gages. Velocities were measured with a Nixon 402 digital flowmeter and a pitot tube.



a. Looking upstream



b. Looking downstream

Figure 5. Configuration 4

Scale Relations

The accepted equations of similitude, based upon the Froudian relations, were used to express the mathematical relations between the dimensions and hydraulic quantities of the model and the prototype. General relations for the transference of model data to prototype equivalents are presented in the following tabulation:

Characteristic	Dimension	Scale Ratio Model:Prototype
Length	$L_r = L$	1:36
Area	$A_r = L_r^2$	1:1,296
Velocity	$V_r = L_r^{1/2}$	1:6
Discharge	$Q_r = L_r^{5/2}$	1:7,776
Time	$T_r = L_r^{1/2}$	1:6

Because of the nature of the hydraulic phenomena involved, certain model data sets can be accepted quantitatively, while other data, such as scour patterns, are reliable only in a qualitative sense. Measurements in the model of discharges, water-surface elevations, velocities, and stability of riprap material can be transferred quantitatively from model to prototype by means of these scale relations. Evidence of scour of the model sand bed, however, is to be considered only qualitatively since the relative erosion that occurs in the prototype with cohesive or fine-grained bed material is not yet possible to reproduce quantitatively in a model. Data on scour tendencies provided a basis for determination of the relative effectiveness of the different designs and indicated the areas most subject to erosion.

Test Procedure

Tests were conducted in the model to observe the flow patterns, velocities, discharges, and overall hydraulic performance of the low sills and the water quality sill. A typical test consisted of setting a discharge and tailwater elevation, and recording the stable pool elevation. Hydraulic performance was documented for each flow condition. Tailwater elevations were measured at a point 457 ft downstream from the end sill (sta 1+00B). During these tests only one gate was operated and there was no leakage through the right or left gate bays.

Riprap stability tests were conducted using the model testing schedule provided by the Pittsburgh District in Appendix A.

3 Tests and Results

Discharge Characteristics

Flow conditions

Tests to determine the discharge characteristics of the spillway with the two spillway crests were conducted for each of the following flow conditions:

a. Free uncontrolled flow. Gate fully open; upper pool unaffected by the tailwater.

b. Submerged uncontrolled flow. Gate fully open; upper pool controlled by the submergence effect of the tailwater.

c. Free controlled flow. Gate partially open; upper pool unaffected by the tailwater; controlled by the particular gate opening with flow under the gate.

d. Submerged controlled flow. Gate partially open; upper pool controlled by both the submergence effect of the tailwater and the gate opening with flow under the gate.

Description of tests

Free uncontrolled flow characteristics were determined by introducing various constant discharges into the model and observing the corresponding upper pool elevation for several tailwater elevations. Sufficient time was allowed for stabilization of the upstream flow conditions. Upper pool elevations were measured at a point 203 ft upstream from the dam face. Total head on the crest H or total head on the gate H_g was computed by adding mean velocity head to the upper pool. Tailwater elevations were measured at a point 457 ft downstream from the end sill. During these tests, the left and right gates were closed and sealed to prevent leakage.

Submerged flow discharge characteristics for both controlled and uncontrolled flows were determined by introducing several constant discharges into the model and varying the tailwater by small increments for each from an

elevation at which no interference in spillway flow was evident to an elevation at which the flow was practically 100 percent submerged. The elevation of the upper pool was noted at each of the tailwater elevations.

Weir capacity

The head-discharge rating curves for free uncontrolled flow are presented in Plates 9-11. The equation for each of these curves is the best empirical fit of the free flow data by the method of least squares.

Calibration data

The basic calibration data, presented in Plates 12-28, show the upper pool elevation corresponding to a particular elevation of the tailwater for a given discharge observed with the low sill (el 696.7), raised sill (el 704.7), and high sill (el 714.0) section models.

Uncontrolled flow data for the low, raised, and high sills of the structure are shown in Plates 12-14. The data for each of the various discharges shown in these plates illustrate the following:

a. The relation between the elevation of the upper pool and the tailwater elevation in the exit channel.

b. The range of tailwater elevations at which the upper pool elevation is constant.

c. The range of tailwater elevations at which the upper pool elevation is controlled by the submergence effect of the tailwater, i.e., the range of submerged uncontrolled flow.

Free and submerged controlled flow data for the low, raised, and high sill gate bays with various gate openings are shown in Plates 15-28. The data for each of the various discharges shown in these plates illustrate the following:

a. The relation between the upper pool elevation and the tailwater elevation in the exit channel for the particular gate opening.

b. The range of tailwater elevations at which the upper pool is constant, i.e., the range at which the flow is free from the submergence effects of the tailwater, and either free uncontrolled or free controlled flow exists depending upon the discharge, gate opening, and head on the weir.

c. The range of tailwater elevations at which the upper pool elevation is controlled by the submergence effect of the tailwater, and the range at which the flow is controlled by both the submergence effect of the tailwater and the particular gate opening.

Discharge-head relations and data for free flow conditions in the low, raised, and high sill gate bays are presented in Plates 9-11. These plots represent partial closure of the gates from the top of the structure (orifice flow under gates) for the low, raised, and high sill gate bays. Tailwater effect on discharge for uncontrolled flow and controlled flow are presented in Plates 29-31 for the low, raised, and high sill gate bays, respectively. The data in these plates represent measured pool elevations.

Analyses of data

The flow conditions and equations used to satisfy the experimental data are as follows:

a. Free uncontrolled flow:

$$Q = CLH^{3/2} \tag{1}$$

where C is a function of H.

b. Submerged uncontrolled flow:

$$Q = C_s Lh\sqrt{2g\Delta H} \tag{2}$$

where C_s is a function of h/H.

c. Free controlled flow:

$$Q = C_g LG_o\sqrt{2gH_g} \tag{3}$$

where C_g is a function of H_g and G_o.

d. Submerged controlled flow:

$$Q = C_{g_s} Lh\sqrt{2g\Delta H} \tag{4}$$

where C_{g_s} is a function of h/G_o.

Symbols used in these equations are defined as follows:

Q = discharge per bay, cfs

L = net length of spillway crest, ft

H = total head on weir (including velocity head), ft

h = tailwater elevation referred to weir crest, ft

g = acceleration due to gravity, ft/sec^2

ΔH = differential between gross head on spillway weir and depth of tailwater referenced to the weir (H - h), ft

G_o = gate opening, ft

H_g = total head on gate (H - $G_o/2$), ft

Quantities determined from the experimental data were substituted in the equations, and the discharge coefficients for the respective flow conditions were computed.

Uncontrolled flow discharge coefficients

Free uncontrolled flow discharge coefficients for the low, raised, and high sill gate bays are presented in Plates 32-34.

Submerged uncontrolled flow discharge coefficients resulting from various degrees of submergence are presented in Plates 35-37.

An analysis of the data was made to distinguish between free and submerged uncontrolled flow. Results of this analysis (Plates 38-40) indicate that a transitional flow regime exists between free and submerged uncontrolled flow.

Controlled flow discharge coefficients

The relations between the free controlled flow discharge coefficient and various gate openings are presented in Plates 41-43. An alternate method of presenting free flow data is shown in Plates 9-11.

The relations between the submerged controlled flow discharge coefficient and the ratio of tailwater depth above the crest to gate opening for the low, raised, and high sill gate bays are presented in Plates 44-46.

Flow regimes

The data were analyzed to define the limits of each flow regime and corresponding discharge equation in terms of dimensionless quantities in order to generalize the results. An investigation of the basic data curves with a constant discharge and either uncontrolled or controlled flow reveals that there is a tailwater elevation at which the upper pool elevation increases with a corresponding increase in the tailwater elevation. This is the elevation at which the tailwater begins to submerge or control the flow, and free flow becomes submerged flow.

The results of efforts to distinguish between free and submerged uncontrolled flows are shown in Plates 38-40. These plates in general illustrate that free uncontrolled flow becomes submerged uncontrolled flow for tailwater submergences (h/H) equal to or greater than 64 percent for the low sill, 68 percent for the raised sill, and 64 percent for the high sill. Similar plots indicate that free and submerged controlled flows can be distinguished by the degree of submergence as indicated in Plates 47-49. Results for both uncontrolled and controlled flow conditions are presented in Tables 1-15.

Velocities and Water-Surface Profiles

Test No.	Pool El	TW El	G_O ft
1	723.7	710.0	Full[1]
2	723.7	715.0	Full[1]
3	723.7	720.0	Full[1]
4	723.7	710.0	One-Half[2] (14 ft)
5	723.7	715.0	One-Half[2] (14 FT)
6	723.7	720.0	One-Half[2] (14 FT)

[1] Full gate opening for sill at el 696.7 = 18.0 ft.
[2] One-half gate opening for sill at el 696.7 = the whole gate opening nearest to one-half the gate height, i.e.,

$$\frac{1}{2}(29) = 14.5, \therefore 14.0$$

Water-surface profiles along the center line of the model, Configuration 1, were measured for the conditions in the accompanying tabulation, as requested by engineers from the Pittsburgh District. Elevation 710.0 is the minimum expected tailwater (TW) elevation, and el 720.0 is close to the maximum expected tailwater elevation for normal pool (el 723.7). Water-surface profiles are plotted in Plates 50-55. At tailwater el 710.0 with a full gate opening and normal pool, the hydraulic jump was swept out of the basin resulting in undular waves and severe turbulence immediately downstream of the stilling basin. Water-surface profile data are tabulated in Tables 16 and 17.

Velocities were measured 1 ft above the streambed for test conditions 1, 3, 4, and 6 and are plotted in Plates 56-59.

Riprap Requirements

Configuration 1

Riprap protection was installed in the model immediately downstream of the end sill as shown in Plates 60 and 61. Gradation curves for the riprap used in the model are shown in Plates 62 and 63. A 96-in.-thick blanket (Class E) simulating protective stone with a D_{50min} of 36 in. was placed for 100 ft downstream of the end sill as shown, followed by a 72-in.-thick blanket (Class D) simulating protective stone with a D_{50min} of 31 in. Sand was placed for 108 ft upstream of the structure to determine the need for upstream protection. Each of the steady-state conditions in the following tabulation was run for 6 hours (prototype), simulating discrete discharges for the computed tailwater hydrograph provided by the Pittsburgh District (Plate 64). Test 10, although not a part of the hydrograph, represents a single gate fully open for a prolonged period with inflow sufficient to maintain the upper pool.

Test No.	Pool El	TW El	G_O ft
7	722.7	711.5	10
8	722.2	712.0	14
9	721.8	712.5	Full[1]
10	723.7	715.2	Full[1]

[1] Full gate opening for sill at el 696.7 = 18.0 ft.

This test hydrograph simulates the rapid opening of one gate to fully open during low flows, which is the most critical condition that might occur in the event of operator error. Each condition was run for 6 hours for a factor of safety. The middle gate was used for these riprap stability tests. The downstream riprap protection remained stable throughout the full range of the tests. The sand began to scour upstream around the pier noses during Test 7 and became increasingly more severe during subsequent tests indicating the need for riprap protection upstream of the structure around the pier noses.

The test schedule satisfies the requirements of EM 1110-2-1605[1] for investigation of half-open and fully open gates at normal pool with minimum tailwater.

Several riprap configurations were installed in the model and tested using test conditions 7-10 to determine the most economical extent and size of riprap required for riverbed protection upstream and downstream of the structure.

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1 Headquarters, U.S. Army Corps of Engineers. (1987 (12 May)). "Hydraulic design of navigation dams," EM 1110-2-1605, U.S. Government Printing Office, Washington, DC.

Riprap was placed in 50-ft-wide by 30-ft-long pads, 36 in. thick (Class A), upstream from the spillway, and centered around each pier. The gradation curve for the riprap used in the test is shown in Plate 65. The riprap failed near the pier noses, and the riverbed scoured between each riprap pad. Riprap was placed along the entire upstream dam face for a distance of 30 ft. This riprap consisted of a 48-in.-thick blanket (Class B) simulating protective stone with a D_{50min} of 22.5 in. The riprap remained stable through the full range of operation with all three gates, the left gate, and the middle gate, respectively. The gradation curve for the riprap used in this test is shown in Plate 66.

The length of the 72-in.-thick riprap blanket in the original downstream protection plan was systematically decreased in 50-ft increments and replaced with a 36-in.-thick blanket (Class A) simulating protective stone with a D_{50min} of 18 in. The computed tailwater hydrograph conditions (Tests 7-9) and Test 10 were run until the 36-in.-thick blanket failed. Riprap stability tests conducted in this fashion indicated the minimum extent of riprap required to protect the downstream exit channel was 188 ft.

In an effort to simulate prototype underwater placement of riprap immediately downstream from the stilling basin, a 100-ft-long, 66-in.-thick riprap blanket (Class C) simulating protective stone with a D_{50min} of 27 in. was placed downstream of the end sill followed by an 88-ft-long, 48-in.-thick riprap blanket (Class B) simulating protective stone with a D_{50min} of 22.5 in. The gradation curves for the riprap used in the model are shown in Plate 67. The downstream end of the riprap blanket was placed in a trench 144 in. wide by 96 in. deep at the sand interface (Plate 68). This design is herein referred to as Option A. Riprap stability tests were run for the conditions in the following tabulation. The downstream riprap remained stable throughout the full range of operation. The sand section scoured, but riprap upstream of the sand section and the existing Dam 2 riprap protection downstream of the sand section launched into the bottom of the scour hole providing some armoring (Figure 6).

Test No.	Pool El	TW El	G_O ft
All Three Gates			
11	723.7	722.5	Full[1]
12	723.7	719.0	10
13	723.7	715.0	4
Left Gate			
14	721.8	712.5	Full[1]
15	723.7	715.2	Full[1]
Middle Gate			
16	721.8	712.5	Full[1]
17	723.7	715.2	Full[1]

[1] Full gate opening for sill at el 696.7 = 18.0 ft.

Velocities were measured for test conditions 11-17. Bottom velocities in the approach and exit areas for Tests 11-17 are plotted in Plates 69-75.

Figure 6. Configuration 1, Option A riprap, scour after two hydrographs

In an effort to reduce excavation during placement of the riprap in the prototype, the elevation of the channel downstream from the riprap was raised 5 ft. This was designated the Option B riprap protection plan (Plate 76). The Option B riprap protection plan involved extending the 66-in.-thick riprap

blanket (Class C) on a 1V on 20H slope from el 687.7 to 695.0 for 146 ft followed by a 90-ft-long blanket of riprap 48 in. thick (Class B) at el 695 and increasing the bed elevation from el 690.0 to 695.0. Riprap stability tests were run for test conditions 6-10. The riprap remained stable throughout the full range of conditions tested.

The Pittsburgh District provided a protection plan in which the riprap immediately downstream from the stilling basin was sloped down and shortened. Because this plan would tie into the existing soft rock downstream from the structure, it would be a more economical design. This was designated the Option C riprap protection plan. The Option C riprap protection plan involved placing the 66-in.-thick riprap (Class C) immediately downstream of the end sill on a 1V on 3H slope for 23.1 ft followed by a 50-ft-long bench at el 680.0 and a 1V on 3H slope for 24 ft down to the top of soft rock at el 672.0. The bed remained at el 672.0 for 33 ft and was sloped at a 1V on 2H slope back up to el 695.0 (Plate 77). Riprap stability tests were run for the conditions in the following tabulation:

			Gate Opening, ft		
Q, cfs	Pool El	TW El	Left G_L	Middle G_M	Right G_R
44,000	721.8	712.5	Full[1]	-	-
44,000	721.8	712.5	-	Full[1]	-
32,500	723.7	713.5	-	14	-
16,500	723.7	718.0	2	4	4
38,700	723.7	720.0	8	10	10
53,500	723.7	720.5	12	14	14
130,000	731.9	730.8	Full[1]	Full[1]	Full[1]
151,000	737.0	737.0	Full[1]	Full[1]	Full[1]
18,700	723.7	712.0	2	4	2
52,500	723.7	716.0	8	10	8
68,000	723.7	718.5	12	14	12
25,000	723.7	715.0	4	4	4
45,000	723.7	719.0	10	10	10
90,000	723.7	722.5	Full[1]	Full[1]	Full[1]

[1] Full gate opening for sill at el 696.7 = 18.0 ft.

The downstream riprap remained stable throughout the full range of operation. Bottom velocities over the layer of exposed soft rock that exists in the prototype were measured and are plotted in Plates 78-91.

Configuration 2

The Option C riprap protection plan was tested in the model immediately downstream of the end sill. Riprap stability tests were run for the conditions in the following tabulation:

			Gate Opening, ft		
Q cfs	Pool El	TW El	Left G_L	Water Quality Gate G_{wq}	Fixed Crest
3,600	723.7	710.0	-	2	None
3,600	723.7	713.0	-	2	None
7,000	723.7	710.5	-	4	None
6,800	723.7	713.5	-	4	None
10,300	723.7	711.0	-	Full[1]	None
10,300	723.7	714.0	-	Full[1]	None
42,000	723.7	715.0	14	Full[1]	None
59,500	723.7	716.0	Full[2]	Full[1]	None
71,000	731.8	730.8	Full[2]	Full[1]	UC[3]

[1] Full gate opening for sill at el 714.0 = 6.0 ft.
[2] Full gate opening for sill at el 696.7 = 18.0 ft.
[3] Uncontrolled flow over fixed crest.

Bottom velocities obtained from these tests are plotted in Plates 92-100.

Configuration 3

After the Pittsburgh District redesigned the structure by raising the sills of the three main gates by 8 ft, all testing of the original sills (configurations 1 and 2) was discontinued. The first riprap protection plan tested with configuration 3 was designated as Option D (Plate 101). The Option D riprap protection plan involved placing riprap simulating protective stone with a D_{50min} of 19 in. (Class F, Plate 102) immediately downstream of the end sill on a 1V on 3H slope for 41.1 ft followed by a 44-ft-long bench at el 678.0 and a 1V on 2H slope for 16 ft down to the top of soft rock at el 670.0. The bed remained at el 670.0 for 25 ft and was sloped at a 1V on 2H slope back up to el 695.0. Riprap stability tests were run for conditions in the following tabulation:

Q cfs	Pool El	TW El	Gate Opening, ft Left (G_L)	Middle (G_M)	Right (G_R)
8,700	723.7	715.0	-	4	-
21,500	723.7	710.0	-	10	-
25,000	723.7	715.0	4	4	4
27,500	723.7	711.0	-	Full[1]	-
93,000	723.7	721.0	Full[1]	Full[1]	Full[1]
29,000	-[2]	717.0	-	Full[1]	-
115,000	-[2]	728.5	Full[1]	Full[1]	Full[1]

[1]Full gate opening for sill el 704.7 = 14.0 ft.
[2]No pool el or data were recorded.

Bottom velocities obtained from the first five tests are plotted in Plates 103-107. The riprap remained stable through the range of discharges tested.

The Pittsburgh District provided a protection plan in which the riprap immediately downstream from the stilling basin was sloped down and shortened. This plan, which would tie into the existing soft rock downstream from the structure, would be a more economical design because of the reduced volume of riprap and excavation. This was designated the Option E riprap protection plan. The Option E riprap protection plan involved placing riprap simulating protective stone with a $D_{50_{min}}$ of 19 in (Class F) immediately downstream of the end sill on a 1V on 3H slope for 65.1 ft down to the top of soft rock at el 670.0. The bed remained at el 670.0 for 25 ft and was sloped at a 1V on 2H slope back up to el 695.0 (Plate 108). Riprap stability tests were run for the conditions in the accompanying tabulation.

The riprap remained stable throughout the range of discharges tested. A sand layer placed immediately upstream of the upstream riprap protection blanket was washed out at 137,000 cfs after 24 hr, but the riprap remained stable with no unraveling at the toe. Bottom velocities obtained from these tests are plotted in Plates 109-120.

Configuration 4

The model was modified to reproduce one low sill (el 704.7), one water quality sill (el 714.0), and a fixed-crest weir (el 723.7). Initially the fixed weir was not actually constructed in the model; the bay was merely blocked from passing any flow. Thus, tests with upper pools above el 723.7 did not

Q cfs	Pool El	TW El	Gate Opening, ft Left (G_L)	Middle (G_M)	Right (G_R)
21,500	723.7	710.0	-	10	-
25,000	723.7	715.0	4	4	4
27,000	723.7	718.5	-	Full[1]	-
27,500	723.7	711.0	-	Full[1]	-
28,500	723.7	714.5	4	6	4
33,000	723.7	720.0	8	8	8
48,000	723.7	717.0	8	10	8
75,000	721.1	720.2	Full[1]	Full[1]	Full[1]
93,000	723.7	721.0	Full[1]	Full[1]	Full[1]
100,000	723.7	720.2	Full[1]	Full[1]	Full[1]
111,000	729.0	728.8	Full[1]	Full[1]	Full[1]
137,000	737.8	737.0	Full[1]	Full[1]	Full[1]

[1]Full gate opening for sill at el 704.7 = 14.0 ft.

represent prototype conditions perfectly. The stability of the Option E riprap protection plan was tested with this configuration using conditions in the following tabulation:

Q cfs	Pool El	TW El	Gate Opening, ft Left (G_L)	Water Quality (G_{wq})	Fixed Crest
6,800	723.7	714.0	-	4	-
7,000	723.7	710.5	-	4	-
10,300	723.7	711.0	-	Full[1]	-
10,300	723.7	714.5	-	Full[1]	-
31,000	723.7	712.0	10	Full[1]	-
36,000	723.7	720.2	Full[2]	Full[1]	-
64,000	731.8	728.8	Full[2]	Full[1]	UC[3]

[1]Full gate opening for sill at el 714.7 = 6.0 ft.
[2]Full gate opening for sill at el 704.7 = 14.0 ft.
[3]Uncontrolled flow over fixed crest.

The riprap remained stable for discharges up to and including 36,000 cfs. Riprap failure along the toe of the riprap layer began immediately after

64,000 cfs was discharged in the model. The scour progressed up the toe as shown in Plate 121 after 64,000 cfs was discharged for 48 hr. Bottom velocities obtained from these tests are plotted in Plates 122-128. The D_{50min} of the riprap was increased from 19 in. to 24 in. (Class G). Upstream return flow below the blocked fixed weir appeared to be related to velocity pulsations in the failure area. Modifying the configuration to permit flow over the fixed weir, washing out most of the return flow, did not eliminate the failure. The riprap failed along the toe with the 64,000-cfs discharge as it did with the smaller D_{50min} of 19 in. The D_{min} of the riprap along the toe was increased from 24 in. to 30 in. (Class H). This riprap protection plan is referred to as the Option F riprap protection plan (Plate 129). Riprap gradations for Classes G and H are shown in Plates 130 and 131.

The Option F riprap protection plan involved placing riprap simulating protective stone with a D_{50min} of 24 in. (Class G) immediately downstream of the end sill on a 1V on 3H slope for 54.1 ft down to a 1V on 3H slope of stone with a D_{min} of 30 in. and a D_{max} of 38.4 in. (Class H) for 11 ft to the top of soft rock at el 670.0. The bed remained at el 670.0 for 25 ft and was sloped at a 1V on 2H slope back up to el 695.0 (Plate 129). Riprap stability tests were run for the following conditions:

			Gage Opening, ft		
Q cfs	Pool El	TW El	Left (G_L)	Water Quality (G_{wq})	Fixed Crest
36,000	723.7	720.2	Full[1]	Full[2]	-
71,000	729.5	728.8	Full[1]	Full[2]	UC[3]
86,500	733.4	732.7	Full[1]	Full[2]	UC[3]
104,000	739.6	737.0	Full[1]	Full[2]	UC[3]

[1]Full gate opening for sill at el 704.7 = 14.0 ft.
[2]Full gate opening for sill at el 714.0 = 6.0 ft.
[3]Uncontrolled flow over fixed crest.

The riprap remained stable for the discharges tested. Bottom velocities obtained from these tests are plotted in Plates 132-135.

An alternate riprap protection plan was designed by the Pittsburgh District to reduce the volume of riprap. The Option G riprap protection plan involved placing riprap simulating protective stone with a D_{min} of 30 in. and a D_{max} of 38.4 in. (Class H, Plate 131) immediately downstream of the end sill on a 1V on 2H slope for 33.4 ft down to the top of soft rock at el 670.0. The bed remained at el 670.0 for 25 ft and was sloped at a 1V on 2H slope back up to el 695.0 (Plate 136). Riprap stability tests were run for conditions in the following tabulation:

Q cfs	Pool El	TW El	Gate Opening, ft Left (G_L)	Water Quality (G_{wq})	Fixed Crest
7,000	723.7	710.5	-	4	-
10,300	723.7	711.0	-	Full[1]	-
21,500	723.7	710.0	10	-	-
27,500	723.7	711.0	Full[2]	-	-
31,000	723.7	712.0	10	Full[1]	-
36,000	723.7	720.2	Full[2]	Full[1]	-
36,500	723,7	718.5	Full[2]	Full[1]	-
71,000	729.5	728.8	Full[2]	Full[1]	UC[3]
86,500	734.0	732.7	Full[2]	Full[1]	UC[3]
104,000	739.6	737.0	Full[2]	Full[1]	UC[3]

[1]Full gate opening for sill at el 714.0 = 6.0 ft.
[2]Full gate opening for sill at el 704.7 = 14.0 ft.
[3]Uncontrolled flow over fixed crest.

The riprap remained stable throughout the range of discharges tested. Bottom velocities obtained from these tests are plotted in Plates 137-146.

No stone protection

Configuration 3. The riprap protection downstream of the structure was removed and the soft stone layer (el 670.0) was exposed to determine the maximum velocities the soft stone layer might be exposed to if no stone protection was provided downstream of the structure. Bottom velocities were measured with flow through the three low sills (el 704.7) for the flow conditions in the following tabulation:

Q cfs	Pool El	TW El	Gate Opening, ft Left (G_L)	Middle (G_M)	Right (G_R)
21,500	723.7	710.0	-	10	-
27,000	723.7	718.5	-	Full[1]	-
28,500	723.7	714.5	4	6	4
27,500	723.7	711.0	-	Full[1]	-
33,000	723.7	720.0	8	8	8
48,000	723.7	717.0	8	10	8

[1]Full gate opening for sill at el 704.7 = 14.0 ft.

Bottom velocities are plotted in Plates 147-152.

Configuration 4. The model was modified to reproduce one low sill (el 704.7), one high sill (el 714.0), and a fixed-crest weir (el 723.7). Bottom velocities were measured over the exposed soft rock layer for the following flow conditions:

			Gate Opening, ft		
Q cfs	Pool El	TW El	Left (G_L)	Water Quality (G_{wq})	Fixed crest
7,000	723.7	710.5	-	4	-
10,300	723.7	711.0	-	Full[1]	-
31,000	723.7	712.0	10	Full[1]	-
36,000	723.7	720.2	Full[2]	Full[1]	-
71,000	729.5	728.8	Full[2]	Full[1]	UC[3]
86,500	733.4	732.7	Full[2]	Full[1]	UC[3]
104,000	739.6	737.0	Full[2]	Full[1]	UC[3]

[1]Full gate opening for sill at el 704.7 = 14.0 ft.
[2]Full gate opening for sill at el 714.0 = 6.0 ft.
[3]Uncontrolled flow over fixed crest.

Bottom velocities are plotted in Plates 153-159.

A test was run to simulate an EM 1110-2-1605[1] recommendation to determine the extent of damage to the downstream riprap protection resulting from the 100-year flood (77,000 cfs) at minimum tailwater (el 721.0) being forced through one gate bay. Flow was blocked off from the water quality gate (sill el 714.0) and the fixed-crest weir (el 723.7) simulating barges jammed in all but one gate bay. After 6 hr of operation, a large scour hole developed upstream of pier 2 and downstream of the gate as shown in Plate 160.

Ice tests

Ice passage was simulated using two sizes of ice, to observe ice impact on the riprap protection and to determine if ice would pass through smaller gate openings. The three crests at el 704.7 were tested. The results of these tests are listed in the following tabulation:

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1 Headquarters, U.S. Army Corps of Engineers. (1987 (12 May)). "Hydraulic design of navigation dams," EM 1110-2-1605, U.S. Government Printing Office, Washington, DC.

Q cfs	G_o, ft	Pool El	TW El	Dimension of Simulated Ice, ft	Visual Observations
21,500	One gate open 10 ft	723.7	710.0	5.5 long 5.5 wide 0.75 thick	Ice passed easily.
25,000	All three gates open 4 ft	723.7	715.0	5.5 long 5.5 wide 0.75 thick	Ice passed slowly. Caught in roller just upstream of baffles
27,500	One gate open full	723.7	711.0	6.0 long 6.0 wide 2.25 thick	Ice passed rapidly.

4 Conclusions

The spillway crest, piers, and stilling basin for both the low- and high-gate bays were satisfactory, and no alterations were made during the model investigation.

Results of tests to determine discharge characteristics of the Monongahela Dam 2 indicated the four possible flow conditions that can be satisfied by the following equations:

a. Free uncontrolled flow:

$$Q = CLH^{3/2} \tag{1 bis}$$

where C is a function of H.

b. Submerged uncontrolled flow:

$$Q = C_s Lh\sqrt{2g\Delta H} \tag{2 bis}$$

where C_s is a function of h/H.

c. Free controlled flow:

$$Q = C_g LG_o\sqrt{2gH_g} \tag{3 bis}$$

where C_g is a function of H_g and G_o.

d. Submerged controlled flow:

$$Q = C_{g_s} L h \sqrt{2g\Delta H} \qquad \text{(4 bis)}$$

where C_{g_s} is a function of h/G_o.

The discharge coefficients applicable to each of these flow conditions and equations are shown in the plates relating the coefficients and the pertinent variable. The limit of each flow regime and the corresponding discharge equation are shown in graphic plots in terms of dimensionless quantities.

Tests indicated that raising the downstream bed 5 ft (from el 690 to el 695) did not cause adverse flow conditions or increase velocities downstream of the structure. This would reduce the required amount of excavation, thereby saving a substantial amount of money in construction costs.

Riprap stability tests indicated that the Option C riprap protection plan remained stable in the model through the full range of operation of the low (el 696.7) and high (el 714.0) gate bays. The Option C riprap protection plan involved placing riprap simulating protective stone with a $D_{50_{min}}$ of 27 in. (Class C, Plate 67) immediately downstream of the end sill on a 1V on 3H slope for 23.1 ft followed by a 50-ft-long bench at el 680.0 and a 1V on 3H slope for 24 ft down to the top of soft rock at el 672.0. The bed remained at el 672.0 for 33 ft and was sloped at a 1V on 2H slope back up to el 695.0 (Plate 77).

Riprap stability tests indicated that the Option F riprap protection plan remained stable in the model through the full range of operation of the low (el 704.7) and high (el 714.0) gate bays. The Option F riprap protection plan involved placing riprap simulating protective stone with a $D_{50_{min}}$ of 24 in. (Class G, Plate 130) immediately downstream of the end sill on a 1V on 3H slope for 54.1 ft down a 1V on 3H slope of stone with a D_{min} of 30 in. and a D_{max} of 38.4 in. (Class H) for 11 ft to the top of soft rock at el 670.0. The bed remained at el 670.0 for 25 ft and was sloped at a 1V on 2H slope back up to el 695.0 (Plate 129).

Riprap stability tests indicated that the Option G riprap protection plan remained stable in the model through the full range of operation of the low (el 704.7) and high (el 714.0) gate bays. The Option G riprap protection plan involved placing riprap simulating protective stone with a $D_{50_{min}}$ of 30 in. (Class H, Plate 131) immediately downstream of the end sill on a 1V on 2H slope for 33.4 ft down to the top of soft rock at el 670.0. The bed remained at el 670.0 for 25 ft and was sloped at a 1V on 2H slope back up to el 695.0 (Plate 136). Because this riprap protection plan was the most economical of the stable riprap plans tested, it is recommended for prototype construction.

As an option, the stone protection downstream of the structure was removed, exposing the soft stone layer (el 670.0) to determine the maximum velocities the soft stone layer would be exposed to if no stone protection was provided downstream of the structure. Bottom velocities of 1.0 to 4.6 fps were measured in the model. Geotechnical engineers in the Pittsburgh District will evaluate the velocities, and a decision will be made to protect the structure with riprap or extend the cutoff wall down through the soft rock layer with no stone protection.

As summarized in the tabulation in the section, "Ice tests," in Chapter 3, ice passage was simulated to observe ice impact on the riprap protection and to determine if ice would pass through smaller gate openings. The crest elevation was 704.7. Passage of 0.75-ft-thick ice began through one gate open 10 ft at normal pool el 723.7 and minimum tailwater el 710.0. Passage of 0.75-ft-thick ice began through all three gates open 4 ft at normal pool el 723.7 and tailwater el 715.0. Passage of 2.25-ft-thick ice began with one gate fully open at normal pool el 723.7 and tailwater el 711.0. The ice did not impact riprap protection because the ice did plunge downward, but remained on the surface.

Table 1
Basic Calibration Data, Submerged Controlled Flow, Crest El 696.7

G_o,ft	Q, cfs	Tailwater El	Headwater El	H_g,ft	h, ft	C_{g_s}	h/Go
2	5,050	700.0	710.8	13.1	3.3	0.53	1.7
	5,050	702.0	713.2	15.5	5.3	0.32	2.6
	5,050	704.2	715.6	17.9	7.5	0.23	3.8
	5,050	705.2	716.7	19.0	8.5	0.20	4.3
	5,050	710.3	722.1	24.4	13.6	0.12	6.8
	5,050	712.1	723.5	25.8	15.4	0.11	7.7
2	6,000	700.0	716.2	18.5	3.3	0.51	1.7
	6,000	702.0	717.0	19.3	5.3	0.33	2.6
	6,000	704.0	720.8	23.1	7.3	0.23	3.6
	6,000	705.0	721.6	23.9	8.3	0.20	4.1
	6,000	707.7	724.3	26.6	11.0	0.15	5.5
4	7,000	705.2	711.2	12.5	8.5	0.38	2.1
	7,000	710.1	716.4	17.7	13.4	0.24	3.3
	7,000	715.0	721.5	22.8	18.3	0.17	4.6
4	8,050	704.6	712.1	13.5	7.9	0.42	2.0
	8,050	710.0	718.4	19.7	13.3	0.24	3.3
	8,050	715.0	723.6	24.9	18.3	0.17	4.6
4	9,000	705.2	714.7	16.0	8.5	0.39	2.1
	9,000	710.0	720.2	21.6	13.3	0.24	3.3
	9,000	712.8	723.7	25.0	16.1	0.19	4.0
4	10,000	705.0	715.9	17.3	8.3	0.41	2.1
	10,000	710.0	722.7	24.0	13.3	0.24	3.3
	10,000	710.5	723.3	24.7	13.8	0.23	3.5
6	10,200	704.1	708.3	8.6	7.4	0.77	1.2
	10,200	705.0	709.0	9.3	8.3	0.70	1.4
	10,200	710.0	715.3	15.7	13.3	0.38	2.2
	10,200	715.2	721.0	21.3	18.5	0.26	3.1
6	12,000	704.2	710.2	10.5	7.5	0.74	1.2
	12,000	705.0	710.4	10.8	8.3	0.70	1.4
	12,000	710.2	717.1	17.4	13.5	0.38	2.3
	12,000	715.0	722.3	22.7	18.3	0.27	3.0
6	15,000	705.0	716.7	17.1	8.3	0.60	1.4

Table 1 (Continued)							
G_o,ft	Q, cfs	Tailwater El	Headwater El	H_g,ft	h, ft	C_{g_s}	h/Go
6	15,000	710.0	721.6	21.9	13.3	0.38	2.2
6	16,900	709.0	723.4	23.8	12.3	0.41	2.1
8	15,000	705.3	711.1	10.5	8.6	0.82	1.1
	15,000	710.0	716.2	15.5	13.3	0.51	1.7
	15,000	715.0	721.5	20.8	18.3	0.36	2.3
	15,000	717.3	723.9	23.2	20.6	0.32	2.6
8	18,000	710.0	718.8	18.2	13.3	0.52	1.7
	18,000	715.2	724.9	24.2	18.5	0.35	2.3
8	20,000	710.0	720.5	19.9	13.3	0.53	1.7
	20,000	711.8	723.5	22.9	15.1	0.44	1.9
8	22,000	707.3	721.9	21.3	10.6	0.61	1.3
	22,000	710.0	723.2	22.6	13.3	0.52	1.7
10	20,000	710.0	716.2	14.6	13.3	0.68	1.3
	20,000	715.0	722.7	21.1	18.3	0.45	1.8
10	22,000	710.0	717.6	16.0	13.3	0.68	1.3
	22,000	715.0	724.0	22.4	18.3	0.45	1.8
10	23,000	710.0	718.8	17.2	13.3	0.66	1.3
	23,000	713.3	723.1	21.5	16.6	0.50	1.7
	23,000	715.0	725.3	23.6	18.3	0.44	1.8
10	26,000	710.0	722.1	20.5	13.3	0.64	1.3
	26,000	711.6	722.8	21.2	14.9	0.59	1.5
12	26,000	710.0	717.3	14.7	13.3	0.82	1.1
	26,000	714.9	722.9	20.3	18.2	0.57	1.5
12	27,000	710.0	718.9	16.4	13.3	0.77	1.1
	27,000	715.0	724.3	21.7	18.3	0.55	1.5
12	29,000	713.8	723.5	20.9	17.1	0.62	1.4
12	30,000	710.0	722.1	19.6	13.3	0.73	1.1
	30,000	711.6	722.4	19.8	14.9	0.69	1.2
14	31,000	715.0	722.3	18.7	18.3	0.71	1.3
	31,000	715.7	723.3	19.7	19.0	0.67	1.4
14	32,000	715.0	722.8	19.3	18.3	0.71	1.3
14	33,000	710.0	720.7	17.2	13.3	0.86	0.9
	33,000	715.0	724.0	20.5	18.3	0.68	1.3
(Sheet 2 of 3)							

Table 1 (Concluded)							
G_o,ft	Q, cfs	Tailwater El	Headwater El	H_g,ft	h, ft	C_{g_s}	h/Go
14	34,000	713.3	723.4	19.9	16.6	0.73	1.2
	34,000	715.0	724.9	21.3	18.3	0.67	1.3
16	37,000	716.0	723.4	18.9	19.3	0.80	1.2
16	38,000	715.0	723.0	18.5	18.3	0.83	1.1
16	39,000	715.0	724.0	19.5	18.3	0.80	1.1

(Sheet 3 of 3)

Table 2
Basic Calibration Data, Submerged Uncontrolled Flow, Crest El 696.7

Q, cfs	Tailwater El	Headwater El	*H* ft	*h* ft	C_s	*h/H*
10,200	704.4	706.3	9.8	7.7	1.08	0.786
	707.1	708.2	11.6	10.4	1.08	0.896
	710.0	710.8	14.2	13.3	0.97	0.937
	715.1	715.5	18.8	18.4	1.00	0.979
	720.0	720.2	23.6	23.3	1.07	0.987
	722.4	722.7	26.0	25.7	0.97	0.988
	723.9	724.0	27.3	27.2	1.12	0.996
20,000	710.0	712.4	15.8	13.3	1.11	0.842
	715.0	716.6	20.0	18.3	0.97	0.915
	720.1	720.9	24.2	23.4	1.09	0.967
	722.0	722.6	26.0	25.3	1.14	0.973
30,000	715.0	718.6	22.1	18.3	0.98	0.828
	718.0	719.7	23.0	21.3	1.21	0.926
	720.2	721.5	24.8	23.5	1.26	0.948
	722.0	723.2	26.5	25.3	1.21	0.955
40,000	716.6	721.4	25.0	19.9	1.04	0.796
	718.0	721.8	25.1	21.3	1.09	0.849
	720.1	723.1	26.4	23.4	1.11	0.886

Table 3
Basic Calibration Data, Free Controlled Flow, Crest El 696.7

G_o ft	Q cfs	Tailwater El	Headwater El	H_g ft	C_g
4.0	7,000	700.0	707.0	8.4	0.685
	8,050	702.0	709.3	10.7	0.696
	9,000	700.0	711.7	13.0	0.706
	10,000	700.0	714.4	15.8	0.713
6.0	10,200	700.0	708.1	8.5	0.662
	12,000	699.4	710.0	10.4	0.702
	15,000	700.0	716.6	17.0	0.687
	16,900	700.0	720.6	21.0	0.696
8.0	15,000	702.0	710.5	9.9	0.674
	18,000	702.0	715.2	14.6	0.668
	20,000	700.0	718.4	17.8	0.671
	22,000	700.0	721.3	20.6	0.686
10.0	20,000	702.0	713.9	12.3	0.646
	22,000	702.0	716.7	15.1	0.641
	23,000	702.0	718.0	16.4	0.644
	26,000	702.0	721.8	20.2	0.655
12.0	26,000	702.0	715.7	13.2	0.676
	27,000	705.0	718.2	15.7	0.644
	29,000	702.0	721.0	18.5	0.637
	30,000	702.0	722.0	19.5	0.642
14.0	31,000	702.0	717.8	14.3	0.663
	32,000	702.0	718.4	15.0	0.669
	33,000	702.0	720.2	16.7	0.653
	34,000	702.0	722.2	18.7	0.636
16.0	37,000	702.0	720.5	16.0	0.654
	38,000	702.0	721.1	16.6	0.660
	39,000	702.0	722.4	17.9	0.652
	40,500	702.0	723.6	19.1	0.656

Table 4
Basic Calibration Data, Free Uncontrolled Flow, Crest El 696.7

Q cfs	Tailwater El	Headwater El	*H* ft	*C*
10,200	701.1	706.2	9.7	3.09
15,000	700.0	709.1	12.6	3.06
20,000	704.0	712.2	15.6	2.94
22,000	704.0	713.3	16.8	2.90
30,000	705.0	717.0	20.6	2.93
35,000	700.0	719.2	22.7	2.93
40,000	710.0	721.0	24.6	2.99

Table 5
Basic Calibration Data, Normal Pool El 723.7, Crest El 696.7

G_o ft	Q cfs	Tailwater El
2.0	5,050	712.3
	6,000	707.1
	6,100	702.0
4.0	7,000	717.1
	8,050	715.1
	9,000	712.7
	10,000	710.8
6.0	10,200	717.6
	12,000	716.3
	15,000	712.1
	16,900	709.8
8.0	15,000	717.1
	18,000	714.2
	20,000	711.7
	22,000	710.5
10.0	20,000	715.6
	22,000	714.7
	23,000	713.6
	26,000	712.2
	27,000	710.0
12.0	26,000	715.4
	27,000	714.3
	29,000	713.7
	30,000	713.2
	32,000	710.0
14.0	31,000	716.1
	32,000	715.9
	33,000	714.7
	34,000	713.7
	36,500	710.0
16.0	37,000	716.2
	38,000	715.7

(Continued)

Table 5 (Concluded)

G_o ft	Q cfs	Tailwater El
16.0	39,000	714.5
	40,500	710.0
Full	10,200	723.6
	20,000	723.4
	30,000	723.0
	42,000	720.0
	45,900	715.0
	45,900	710.0

Table 6
Basic Calibration Data, Submerged Controlled Flow, Crest El 714.0

G_o ft	Q cfs	Tailwater El	Headwater El	H_g ft	h ft	C_{g_s}	h/G_o
2.0	3,600	717.0	725.8	10.8	3.0	0.46	1.5
4.0	5,100	720.3	724.5	8.5	6.3	0.45	1.6
	5,100	725.1	733.7	17.7	11.1	0.18	2.8
4.0	6,000	720.0	725.4	10.4	6.0	0.49	1.5
4.0	7,000	720.3	728.5	12.5	6.3	0.44	1.6

Table 7
Basic Calibration Data, Submerged Uncontrolled Flow, Crest El 714.0

Q cfs	Tailwater El	Headwater El	H ft	h ft	C_s	h/H
5,100	720.3	720.8	6.8	6.3	1.34	0.930
	725.0	725.2	11.2	11.0	1.17	0.982
8,000	725.0	725.5	11.5	11.0	1.16	0.956
10,200	720.0	723.6	9.6	6.0	1.01	0.625
	725.1	725.7	11.7	11.1	1.37	0.950

Table 8
Basic Calibration Data, Free Controlled Flow, Crest El 714.0

G_o ft	Q cfs	Tailwater El	Headwater El	H_g ft	C_g
2.0	3,600	709.5	723.5	8.5	0.699
4.0	5,100	710.1	720.8	4.8	0.656
	6,000	710.0	722.5	7.5	0.621
	7,000	710.0	725.1	9.1	0.656

Table 9
Basic Calibration Data, Free Uncontrolled Flow, Crest El 714.0

Q cfs	Tailwater El	Headwater El	*H* ft	*C*
5,100	710.2	719.9	5.9	3.17
8,000	710.0	722.2	8.2	3.09
10,200	710.0	723.6	9.6	3.12

Table 10
Basic Calibration Data, Normal Pool El 723.7, Crest El 714.0

G_o ft	*Q* cfs	Tailwater El
2.0	3,600	715.3
4.0	5,100	719.2
	6,000	717.0
	6,500	714.0
	6,500	710.6
FULL	5,100	723.6
	8,000	722.8
	10,200	722.1

Table 11
Basic Calibration Data, Submerged Controlled Flow, Crest El 704.7

G_o ft	Q cfs	Tailwater El	Headwater El	H_g ft	h ft	C_{g_s}	h/G_o
4.0	5,100	710.9	713.9	7.2	6.2	0.54	1.5
	5,100	711.2	714.4	7.7	6.5	0.50	1.6
	5,100	712.0	715.3	8.6	7.3	0.43	1.8
	5,100	713.3	716.6	9.9	8.6	0.37	2.2
	5,100	714.2	717.7	11.0	9.5	0.33	2.4
	5,100	715.8	719.3	12.6	11.1	0.28	2.8
	5,100	717.0	720.6	13.9	12.3	0.25	3.1
	5,100	718.2	721.8	15.1	13.5	0.23	3.4
	5,100	720.7	724.4	17.7	16.0	0.19	4.0
4.0	6,500	711.8	717.5	10.8	7.1	0.44	1.8
	6,500	712.0	718.0	11.3	7.3	0.41	1.8
	6,500	712.4	718.3	11.6	7.7	0.39	1.9
	6,500	712.5	718.5	11.8	7.8	0.38	2.0
	6,500	713.2	719.2	12.5	8.5	0.35	2.1
	6,500	714.0	720.2	13.5	9.3	0.32	2.3
	6,500	714.3	720.4	13.7	9.5	0.31	2.4
	6,500	715.3	721.5	14.8	10.6	0.28	2.7
	6,500	716.0	722.2	15.5	11.3	0.26	2.8
	6,500	716.2	722.5	15.8	11.5	0.26	2.9
	6,500	717.3	723.5	16.8	12.6	0.23	3.1
	6,500	717.8	724.0	17.3	13.1	0.23	3.3
4.0	8,000	711.0	718.8	12.1	6.3	0.52	1.6
	8,000	712.1	720.3	13.6	7.4	0.43	1.8
	8,000	713.2	722.2	15.5	8.5	0.36	2.1
	8,000	713.5	722.6	15.9	8.8	0.34	2.2
	8,000	714.0	723.3	16.6	9.3	0.32	2.3
	8,000	714.5	724.3	17.6	9.8	0.30	2.4
6.0	5,100	712.6	713.6	5.9	7.9	0.73	1.3
	5,100	713.3	714.5	6.8	8.6	0.62	1.4
	5,100	714.1	715.4	7.7	9.4	0.55	1.6
	5,100	714.4	715.7	8.0	9.6	0.53	1.6
	5,100	715.2	716.5	8.8	10.5	0.48	1.8

(Sheet 1 of 4)

Table 11 (Continued)

G_o ft	Q cfs	Tailwater El	Headwater El	H_g ft	h ft	C_{g_s}	h/G_o
6.0	5,100	715.3	716.7	9.0	10.6	0.47	1.8
	5,100	716.6	718.1	10.4	11.9	0.40	2.0
	5,100	717.8	719.2	11.5	13.1	0.37	2.2
	5,100	719.0	720.4	12.7	14.3	0.34	2.4
	5,100	720.4	721.9	14.2	15.7	0.30	2.6
	5,100	721.7	723.2	15.5	17.0	0.28	2.8
	5,100	721.8	723.3	15.6	17.1	0.27	2.9
	5,100	722.1	723.6	15.9	17.4	0.27	2.9
	5,100	722.7	724.2	16.5	18.0	0.26	3.0
6.0	8,000	711.0	713.9	6.2	6.3	0.84	1.0
	8,000	712.5	715.4	7.7	7.8	0.68	1.3
	8,000	713.3	716.8	9.1	8.6	0.57	1.4
	8,000	713.9	717.5	9.8	9.2	0.52	1.5
	8,000	714.7	718.5	10.8	10.0	0.47	1.7
	8,000	715.5	719.4	11.7	10.8	0.43	1.8
	8,000	716.5	720.4	12.7	11.8	0.39	2.0
	8,000	717.5	721.5	13.8	12.8	0.36	2.1
	8,000	718.6	722.7	15.0	13.9	0.32	2.3
	8,000	719.9	723.9	16.2	15.2	0.30	2.5
6.0	10,000	711.4	716.9	9.2	6.7	0.72	1.1
	10,000	712.2	717.0	9.3	7.5	0.69	1.3
	10,000	713.1	717.8	10.1	8.4	0.62	1.4
	10,000	713.6	718.9	11.2	8.9	0.55	1.5
	10,000	713.8	719.4	11.7	9.1	0.53	1.5
	10,000	714.1	719.8	12.1	9.4	0.51	1.6
	10,000	714.9	720.9	13.2	10.2	0.46	1.7
	10,000	715.5	721.8	14.1	10.8	0.42	1.8
	10,000	717.0	723.4	15.7	12.3	0.36	2.1
	10,000	717.8	724.2	16.5	13.1	0.34	2.2
6.0	12,000	712.3	720.9	13.2	7.6	0.61	1.3
	12,000	712.9	721.2	13.5	8.2	0.58	1.4
	12,000	713.8	721.8	14.1	9.1	0.53	1.5
	12,000	714.6	723.2	15.5	9.9	0.47	1.6

(Sheet 2 of 4)

Table 11 (Continued)							
G_o ft	Q cfs	Tailwater El	Headwater El	H_g ft	h ft	C_{g_s}	h/G_o
6.0	12,000	715.4	724.6	16.9	10.7	0.42	1.8
8.0	10,000	714.4	716.3	7.6	9.7	0.84	1.2
	10,000	716.0	718.8	10.1	11.3	0.60	1.4
	10,000	716.3	719.0	10.3	11.6	0.60	1.5
	10,000	717.0	719.9	11.2	12.3	0.54	1.5
	10,000	717.3	720.1	11.4	12.6	0.53	1.6
	10,000	718.5	721.4	12.7	13.8	0.48	1.7
	10,000	719.5	722.4	13.7	14.8	0.44	1.8
	10,000	720.3	723.4	14.7	15.6	0.41	2.0
	10,000	721.4	724.4	15.7	16.7	0.39	2.1
8.0	12,000	715.2	718.7	10.0	10.5	0.69	1.3
	12,000	716.0	720.3	11.6	11.3	0.58	1.4
	12,000	716.8	721.0	12.3	12.1	0.55	1.5
	12,000	717.0	721.6	12.9	12.3	0.51	1.5
	12,000	717.5	721.9	13.2	12.8	0.50	1.6
	12,000	718.1	722.6	13.9	13.4	0.48	1.7
	12,000	719.1	723.6	14.9	14.4	0.44	1.8
	12,000	719.8	724.4	15.7	15.1	0.42	1.9
8.0	15,000	712.5	719.6	10.9	7.8	0.82	1.0
	15,000	714.0	719.9	11.2	9.3	0.75	1.2
	15,000	715.0	720.5	11.8	10.3	0.70	1.3
	15,000	715.5	720.9	12.2	10.8	0.67	1.3
	15,000	716.2	722.3	13.6	11.5	0.60	1.4
	15,000	716.4	722.8	14.1	11.7	0.57	1.5
	15,000	717.5	724.4	15.7	12.8	0.51	1.6
8.0	17,000	713.3	722.7	14.0	8.6	0.73	1.1
	17,000	714.2	722.8	14.1	9.5	0.69	1.2
	17,000	714.8	723.0	14.3	10.1	0.67	1.3
	17,000	715.6	723.5	14.8	10.9	0.63	1.4
	17,000	716.3	724.4	15.7	11.6	0.58	1.5
10.0	10,000	715.7	716.6	6.9	11.0	1.09	1.1
	10,000	717.3	718.7	9.0	12.6	0.77	1.3
	10,000	717.8	719.2	9.5	13.1	0.73	1.3

(Sheet 3 of 4)

Table 11 (Concluded)

G_o ft	Q cfs	Tailwater El	Headwater El	H_g ft	h ft	C_{g_s}	h/G_o
10.0	10,000	718.5	720.0	10.3	13.8	0.66	1.4
	10,000	719.6	721.3	11.6	14.9	0.58	1.5
	10,000	720.9	722.6	12.9	16.2	0.54	1.6
	10,000	722.1	723.9	14.2	17.4	0.49	1.7
10.0	15,000	716.4	718.3	8.6	11.7	1.06	1.2
	15,000	717.9	721.9	12.2	13.2	0.64	1.3
	15,000	718.1	722.2	12.5	13.4	0.63	1.3
	15,000	718.8	723.1	13.4	14.1	0.58	1.4
	15,000	719.5	723.9	14.2	14.8	0.55	1.5
10.0	17,000	716.6	720.7	11.0	11.0	0.87	1.1
	17,000	717.6	722.8	13.1	12.6	0.67	1.3
	17,000	718.4	723.9	14.2	13.1	0.63	1.3
10.0	20,000	712.2	722.4	12.7	7.5	0.94	0.8
	20,000	713.1	722.5	12.8	8.4	0.88	0.8
	20,000	714.3	722.7	13.0	9.6	0.81	1.0
	20,000	714.7	722.9	13.2	10.0	0.79	1.0
	20,000	716.4	723.4	13.7	11.7	0.73	1.2
	20,000	717.7	724.6	14.9	13.0	0.66	1.3
10.0	20,500	714.7	723.4	13.7	10.0	0.79	1.0
	20,500	716.1	723.7	14.0	11.4	0.74	1.1
12.0	5,100	722.9	722.9	12.2	18.2	-	1.5
	5,100	721.0	721.0	10.3	16.3	-	1.4
	5,100	718.9	718.9	8.2	14.2	-	1.2
12.0	10,000	722.0	723.0	12.3	17.3	0.65	1.4
	10,000	719.9	720.8	10.1	15.2	0.78	1.3
	10,000	717.9	718.5	7.8	13.2	1.11	1.1
	10,000	717.6	718.1	7.4	12.9	1.24	1.1
12.0	15,000	718.0	719.4	8.7	13.3	1.08	1.1
	15,000	720.0	722.4	11.7	15.3	0.72	1.3
	15,000	722.0	724.6	13.9	17.3	0.61	1.4
12.0	25,700	710.0	723.7	13.0	5.3	1.48	0.4
	25,700	712.0	723.7	13.0	7.3	1.16	0.4
	25,700	714.0	723.7	13.0	9.3	1.01	0.4

(Sheet 4 of 4)

Table 12
Basic Calibration Data, Submerged Uncontrolled Flow, Crest El 704.7

Q cfs	Tailwater El	Headwater El	*H* ft	*h* ft	C_s	*h/H*
10,000	713.3	714.5	9.8	8.6	1.21	0.9
	714.4	715.6	10.9	9.7	1.09	0.9
	716.3	717.0	12.3	11.6	1.12	0.9
	718.6	719.1	14.4	13.9	1.15	1.0
	721.1	721.4	16.7	16.4	1.29	1.0
	723.4	723.6	18.9	18.7	1.30	1.0
	724.6	724.8	20.1	19.9	1.50	1.0
	725.7	725.8	21.1	21.0	1.65	1.0
15,000	715.0	716.9	12.2	10.3	1.18	0.8
	715.7	717.5	12.8	11.0	1.16	0.9
	715.9	717.7	13.0	11.2	1.15	0.9
	717.4	718.7	14.0	12.7	1.16	0.9
	719.0	720.1	15.4	14.3	1.14	0.9
	720.5	721.3	16.6	15.8	1.18	1.0
	721.6	722.4	17.7	16.9	1.11	1.0
	723.3	724.0	19.3	18.6	1.13	1.0
20,000	716.4	719.2	14.5	11.7	1.16	0.8
	718.6	720.8	16.1	13.9	1.12	0.9
	720.7	722.3	17.6	16.0	1.11	0.9
	721.0	722.6	17.9	16.3	1.09	0.9
	722.5	724.0	19.3	17.8	1.04	0.9
25,000	717.9	721.8	17.1	13.2	1.09	0.8
	719.7	722.6	17.9	15.0	1.11	0.8
	720.9	723.5	18.8	16.2	1.09	0.9

Table 13 Basic Calibration Data, Free Controlled Flow, Crest El 704.7					
G_o ft	Q cfs	Tailwater El	Headwater El	H_g ft	C_g
4.0	5,100	710.1	712.2	5.5	0.619
	6,500	711.8	717.5	10.8	0.561
	8,000	710.2	718.6	11.9	0.657
6.0	8,000	710.2	713.7	6.0	0.615
	10,000	710.5	716.8	9.1	0.627
	12,000	710.6	720.8	13.1	0.627
8.0	15,000	711.3	719.5	10.8	0.646
	17,000	710.8	722.6	13.9	0.646
10.0	20,000	709.3	722.3	12.6	0.637
	20,500	710.0	722.9	13.2	0.639
	20,800	710.0	723.7	14.0	0.630
	21,000	710.0	724.0	14.3	0.630
	22,000	710.0	725.6	15.9	0.625

Table 14 Basic Calibration Data, Free Uncontrolled Flow, Crest El 704.7				
Q cfs	Tailwater El	Headwater El	H ft	C
10,000	710.0	714.4	9.7	3.00
15,000	710.6	716.4	11.7	3.40
20,000	710.0	719.1	14.4	3.32
25,000	714.2	721.7	17.0	3.25

Table 15
Basic Calibration Data, Normal Pool El 723.7, Crest El 704.7

G_o ft	Q cfs	Tailwater El
4.0	5,100	720.1
	6,500	717.5
	8,000	714.2
	9,700	710.0
6.0	5,100	722.2
	8,000	719.7
	10,000	717.3
	12,000	714.9
	13,700	712.0
	14,200	710.0
8.0	5,100	722.8
	10,000	720.6
	12,000	719.1
	15,000	717.0
	17,000	715.7
	17,500	714.0
	18,000	710.0
10.0	5,100	723.4
	10,000	721.9
	15,000	719.3
	17,000	718.2
	20,000	716.7
	20,500	715.7
	20,800	713.2
	20,800	711.9
	20,800	710.0
12.0	5,100	723.5
	10,000	722.7
	15,000	721.3
	24,000	718.5
	25,700	714.0
	25,700	712.0

(Continued)

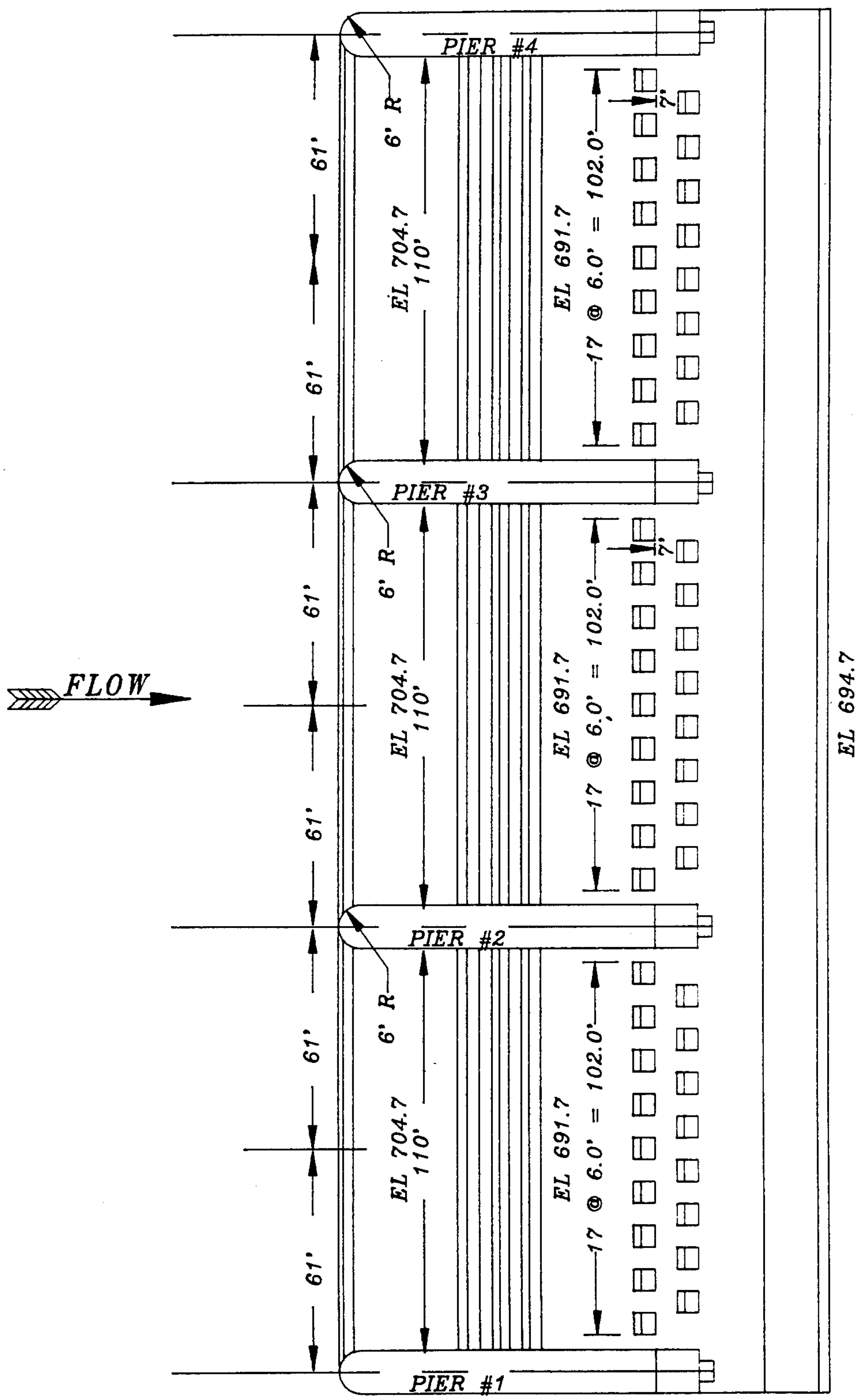
Table 15 (Concluded)		
G_o ft	Q cfs	Tailwater El
12.0	25,700	710.0
FULL	5,100	723.7
	10,000	723.4
	15,000	722.9
	20,000	722.1
	25,000	721.0
	27,000	718.0
	27,500	716.0
	27,500	714.0
	27,500	712.0

Table 16
Type 1 Design, Water-Surface Elevations, Gate Fully Open

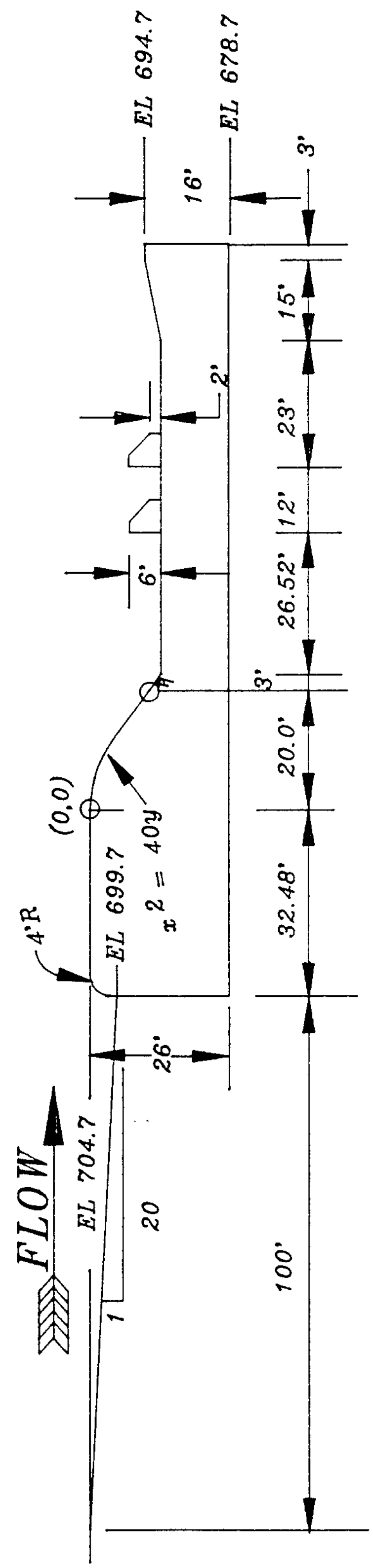
Sta	45,900 cfs TW El 710.0	45,900 cfs TW El 715.0	42,000 cfs TW El 720.0
7+00A	723.7	723.7	723.7
6+50A	723.7	723.7	723.7
6+00A	723.4	723.0	723.7
5+50A	723.0	719.0	723.4
5+00A	718.7	709.2	722.0
4+50A	702.0	714.9	716.2
4+00A	711.5	714.8	719.6
3+50A	705.8	714.4	719.9
3+00A	712.0	714.4	720.0
2+50A	709.4	714.5	720.0
2+00A	706.6	714.4	719.8
1+50A	709.8	714.5	719.8
1+00A	709.9	714.7	719.8
0+50A	709.7	715.0	720.0
0+00	710.0	715.0	720.0
0+50B	710.0	715.0	720.0
1+00B	710.0	715.0	720.0
1+50B	710.0	-	-

Table 17
Type 1 Design, Water-Surface Elevations, Gate Half Open

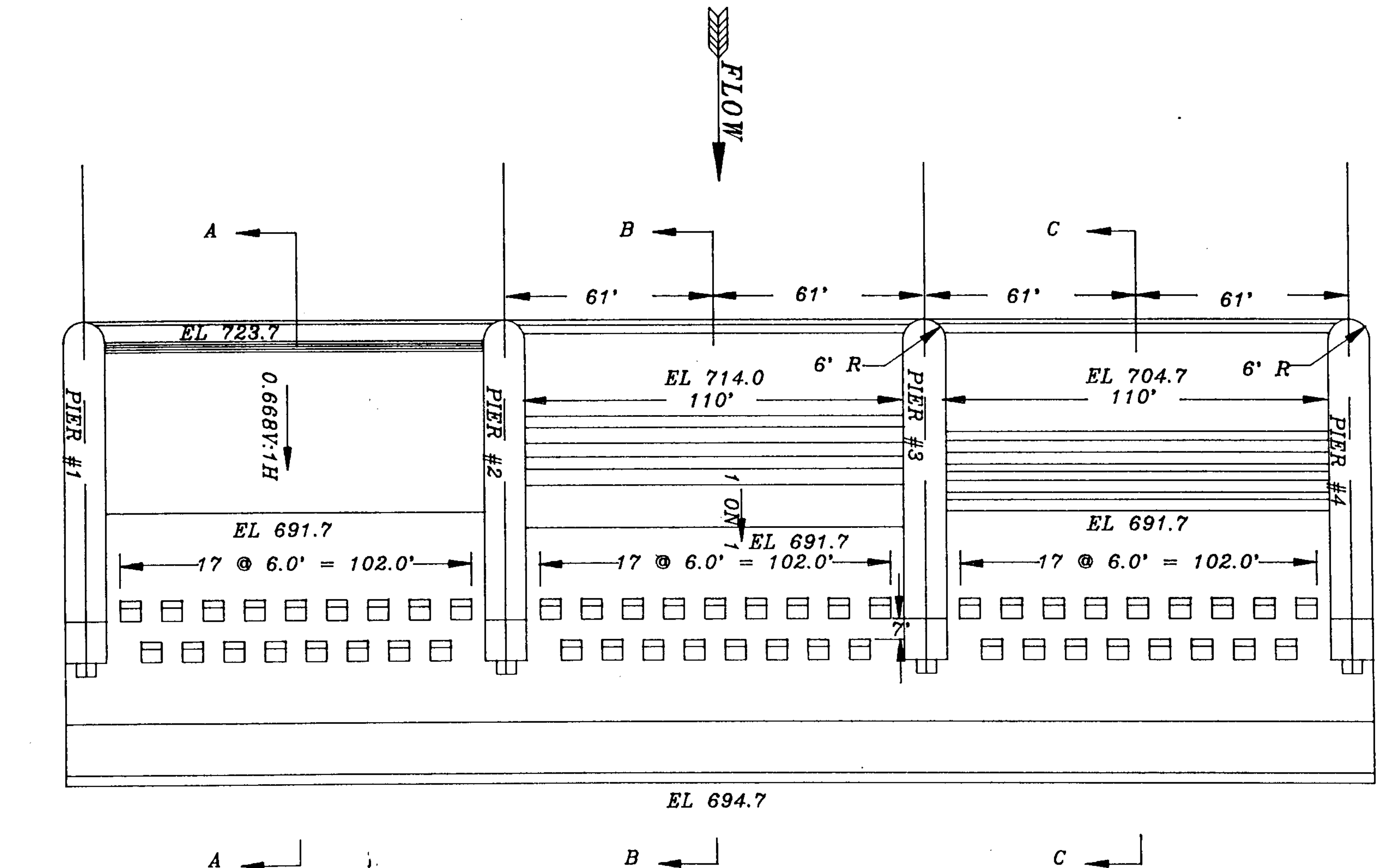
Sta	34,600 cfs TW El 710.0	32,400 cfs TW El 715.0	18,300 cfs TW El 720.0
7+00A	723.7	723.7	723.7
6+50A	723.9	723.7	723.7
6+00A	723.9	723.7	723.7
5+50A	723.7	723.7	723.6
5+00A	723.0	723.0	723.6
4+50A	704.8	709.7	718.7
4+00A	710.3	714.6	718.7
3+50A	708.9	714.6	720.0
3+00A	711.5	714.8	719.8
2+50A	710.8	718.1	719.7
2+00A	707.9	714.3	719.6
1+50A	708.7	714.3	719.6
1+00A	709.3	714.3	719.6
0+50A	709.9	714.7	719.7
0+00	709.9	714.7	719.8
0+50B	710.0	715.0	720.0
1+00B	710.0	715.0	720.0
1+50B	710.0	715.0	-



CONFIGURATION 3
PLAN VIEW

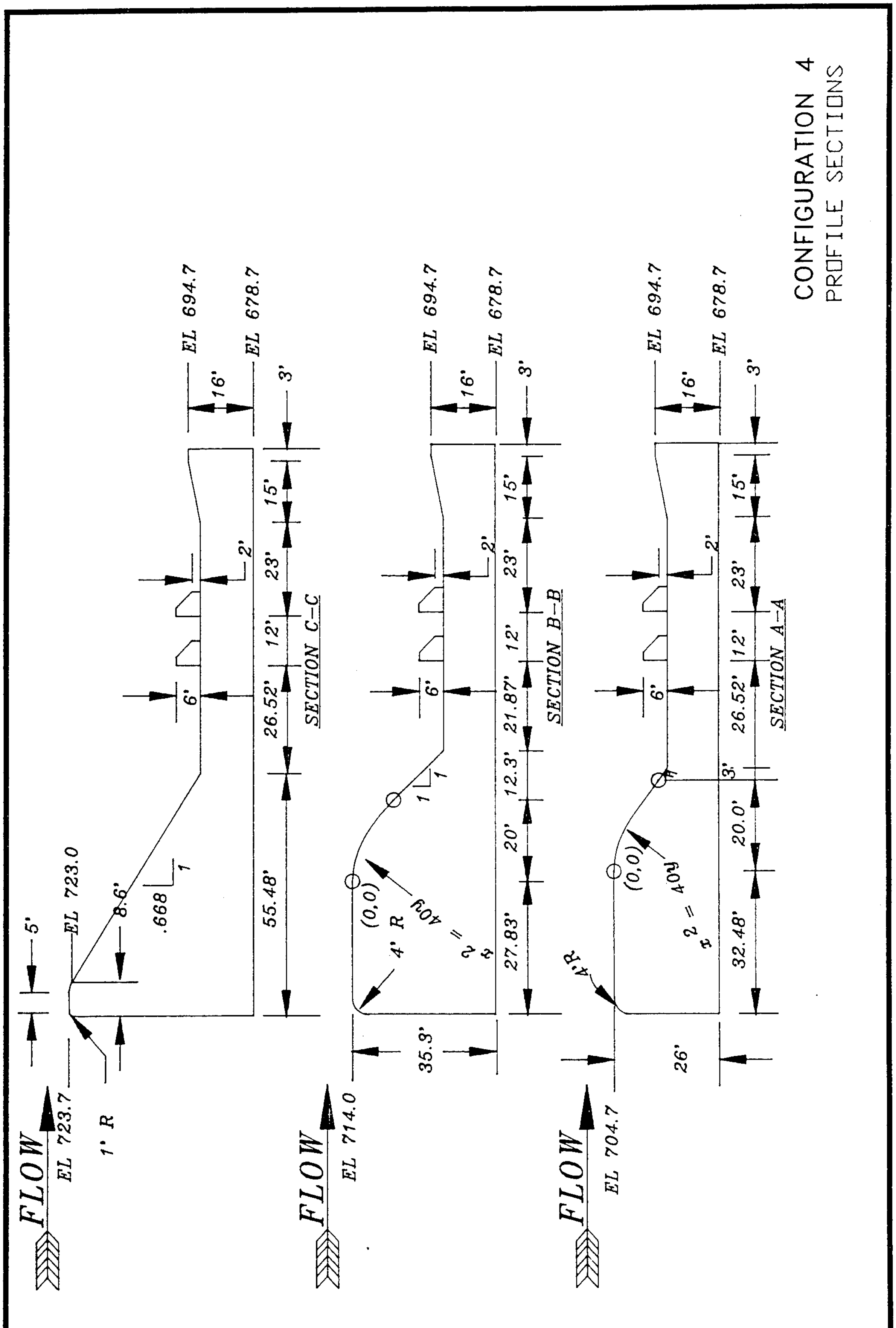


CONFIGURATION 3
PROFILE SECTION



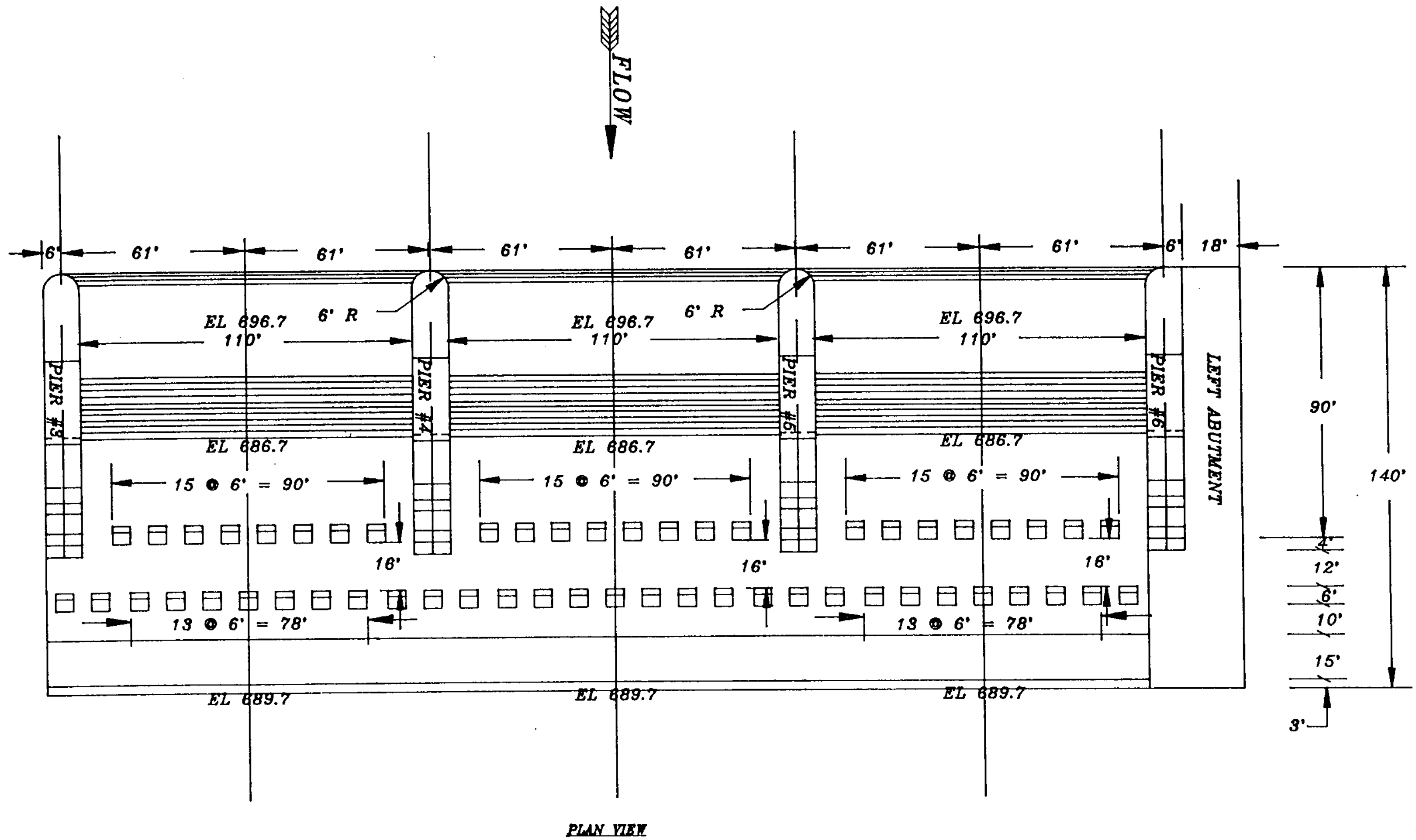
NOTE: SECTIONS A-A, B-B, AND C-C ARE SHOWN IN PLATE 4.

CONFIGURATION 4
PLAN VIEW

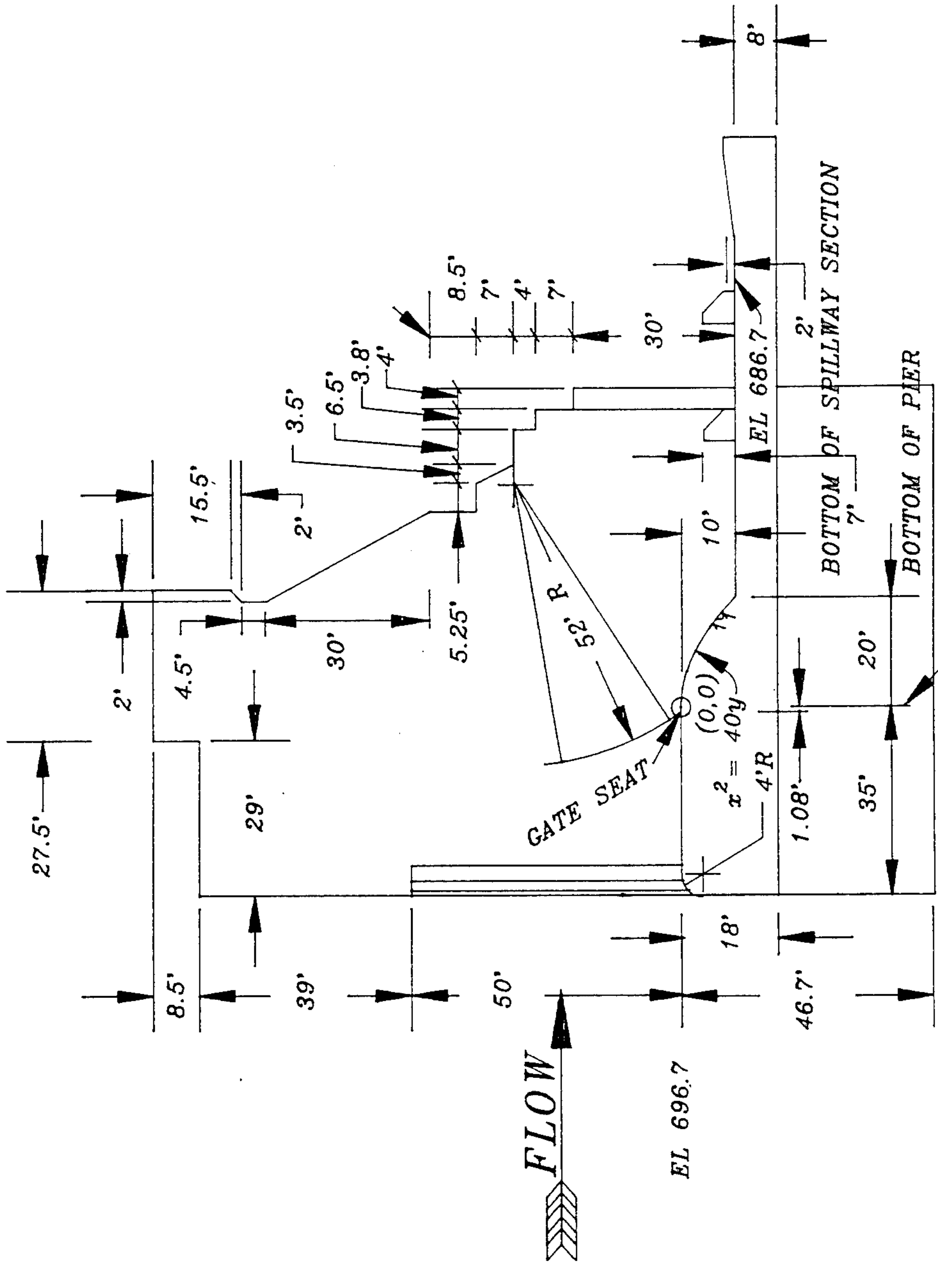


CONFIGURATION 4
PROFILE SECTIONS
SECTION C–C
SECTION B–B
SECTION A–A
FLOW
EL 723.7
EL 723.0
EL 714.0
EL 704.7
EL 694.7
EL 678.7
1' R
4' R
4'R
$x^2 = 40y$
(0,0)
.668
8.6'
5'
35.3'
26'
16'
3'
15'
23'
2'
12'
6'
26.52'
21.87'
12.3'
20'
20.0'
55.48'
27.83'
32.48'

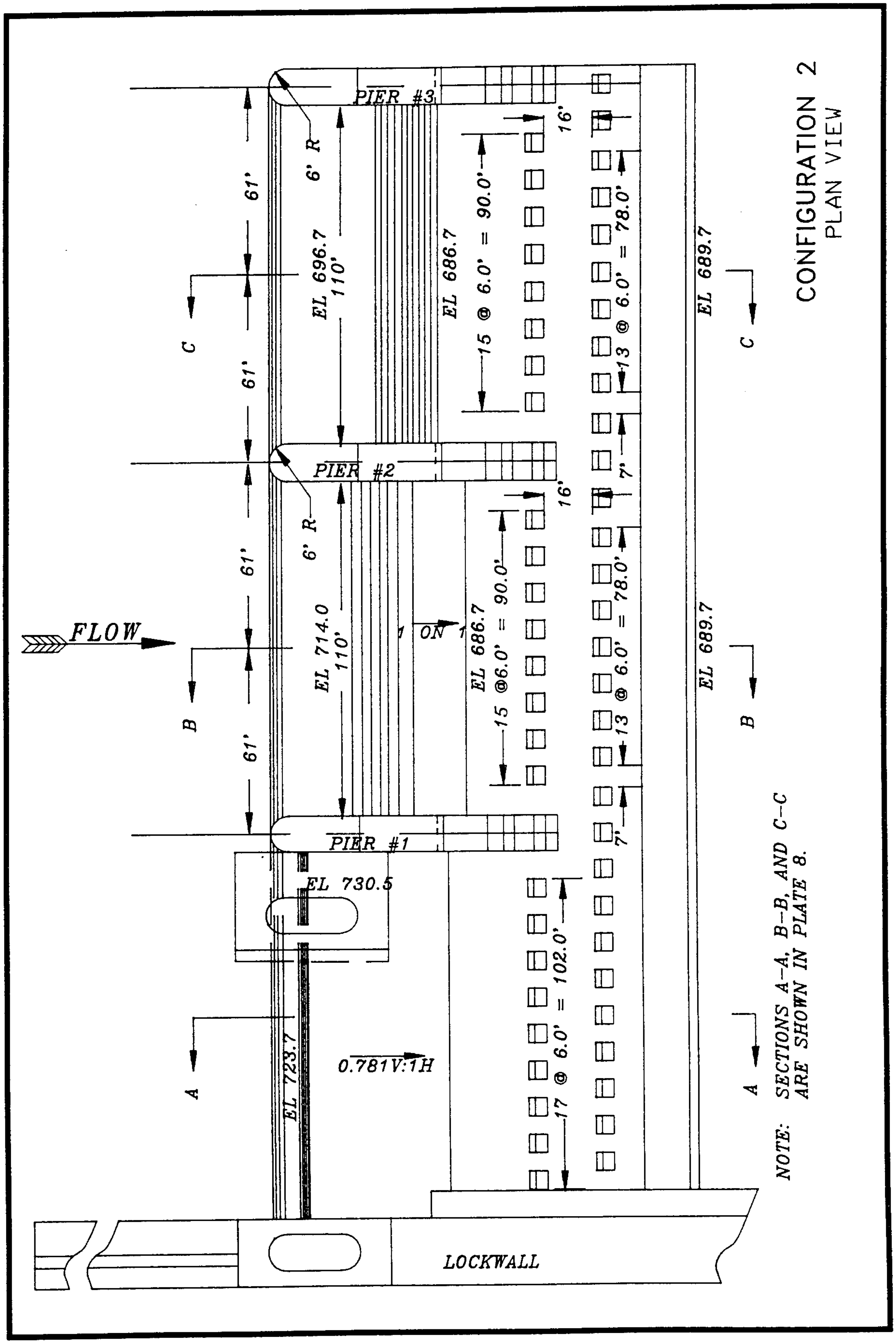
Plate 4

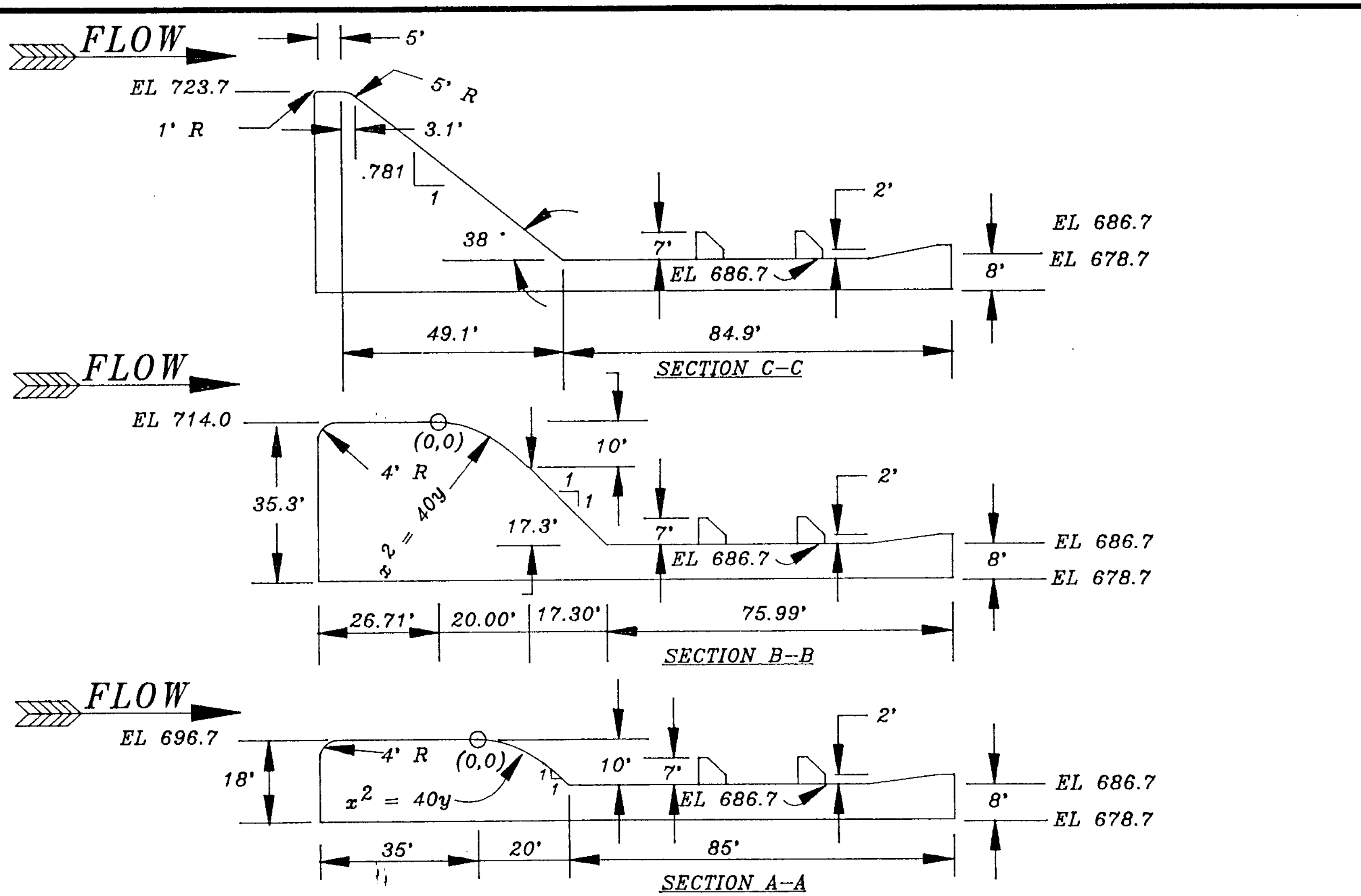


CONFIGURATION 1
ORIGINAL DESIGN
PLAN VIEW

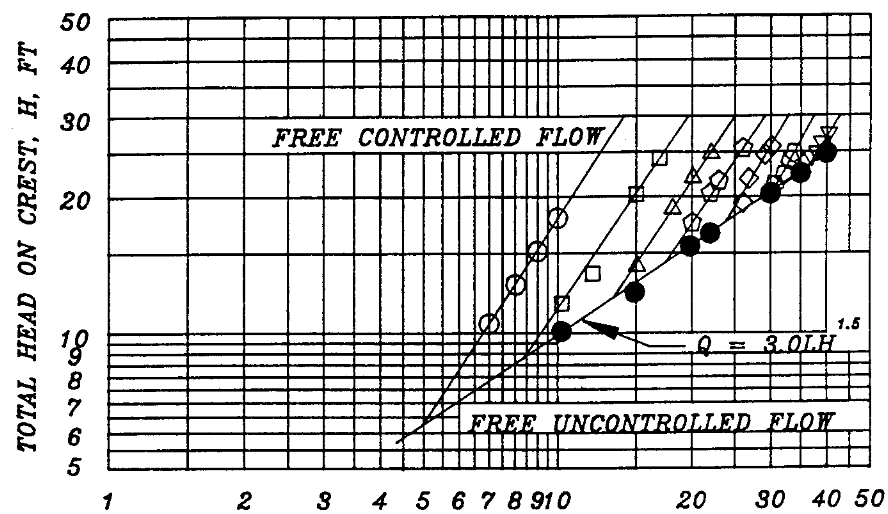


CONFIGURATION 1
ORIGINAL DESIGN
PROFILE VIEW


CONFIGURATION 2
PLAN VIEW
FLOW
PIER #1
PIER #2
PIER #3
6' R
6' R
61'
61'
61'
61'
110'
110'
EL 696.7
EL 714.0
EL 686.7
EL 686.7
EL 689.7
EL 689.7
EL 730.5
EL 723.7
1 ON 1
0.781V:1H
15 @ 6.0' = 90.0'
15 @6.0' = 90.0'
13 @ 6.0' = 78.0'
13 @ 6.0' = 78.0'
17 @ 6.0' = 102.0'
16'
16'
7'
7'
A
A
B
B
C
C
LOCKWALL
NOTE: SECTIONS A–A, B–B, AND C–C ARE SHOWN IN PLATE 8.



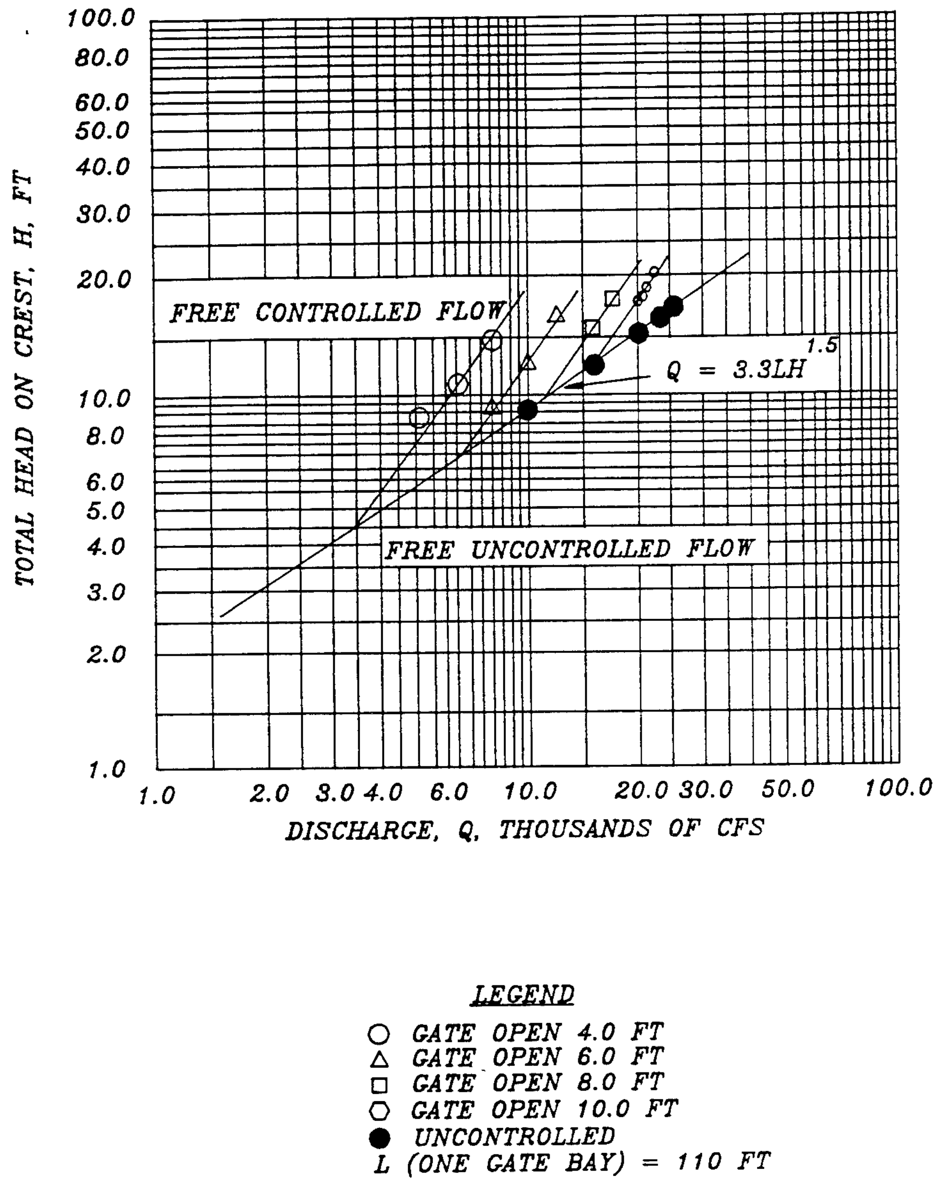
CONFIGURATION 2
PROFILE SECTIONS



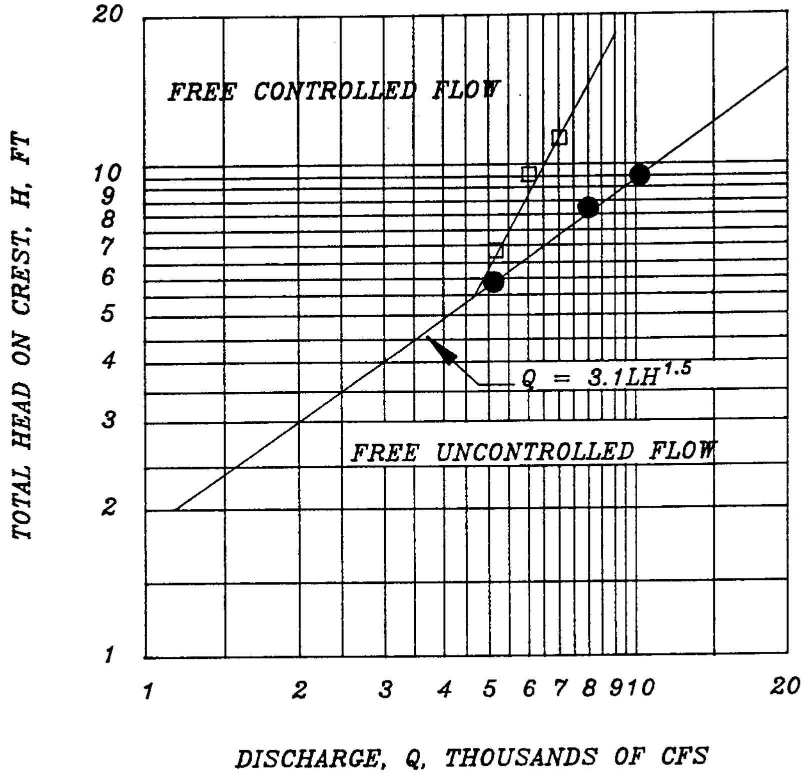
LEGEND

○ *GATE OPEN 4.0 FT*
□ *GATE OPEN 6.0 FT*
△ *GATE OPEN 8.0 FT*
⬠ *GATE OPEN 10.0 FT*
◇ *GATE OPEN 12.0 FT*
⬡ *GATE OPEN 14.0 FT*
▽ *GATE OPEN 16.0 FT*
● *UNCONTROLLED*
L (ONE GATE BAY) = 110 FT

DISCHARGE–HEAD
RELATIONSHIP
FOR FREE FLOW, LOW GATE BAY
CREST ELEVATION 696.7



DISCHARGE–HEAD
RELATIONSHIP
FOR FREE FLOW
CREST ELEVATION 704.7



<u>LEGEND</u>

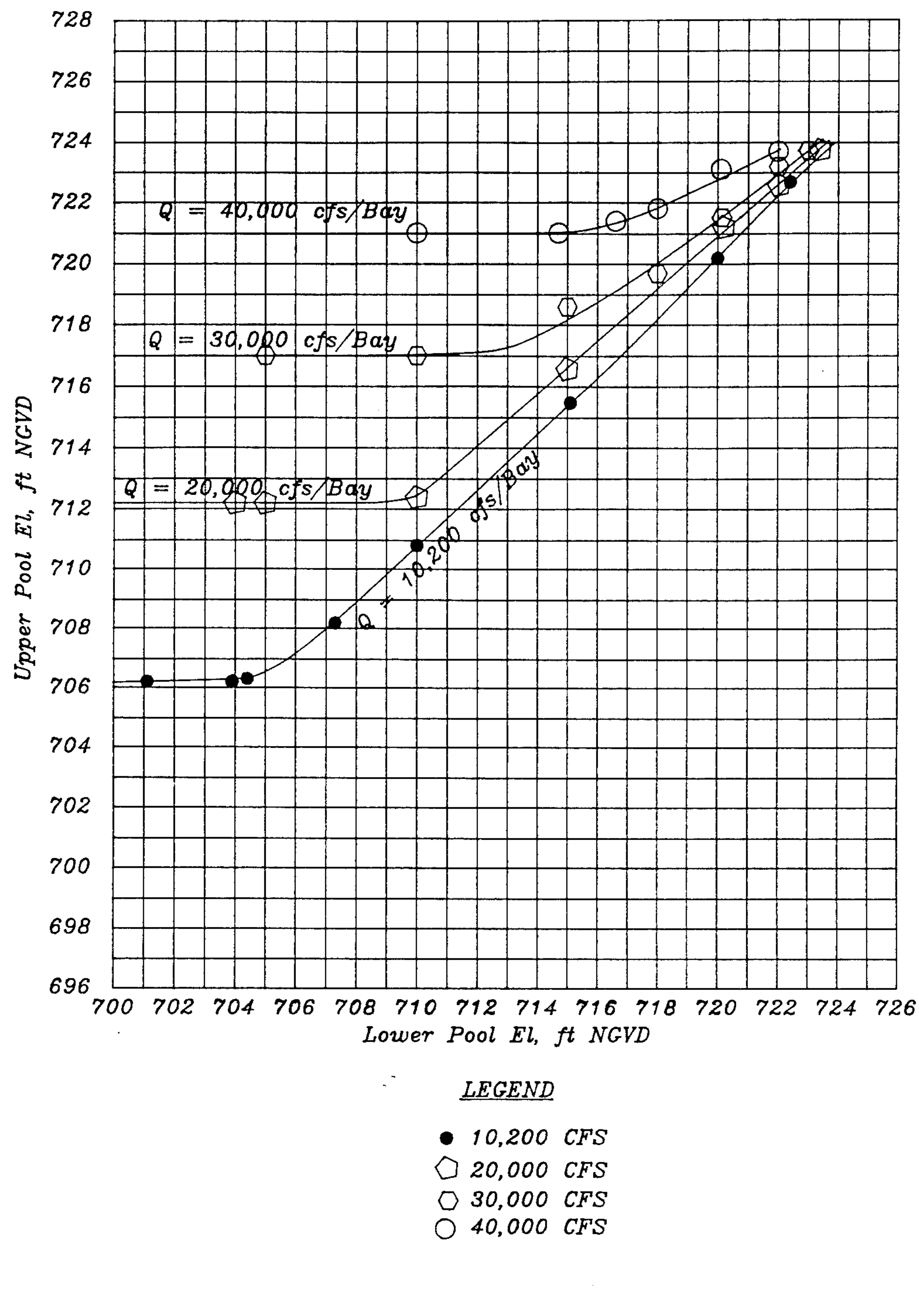
□ GATE OPEN 4.0 FT

● UNCONTROLLED

L (ONE GATE BAY) = 110 FT

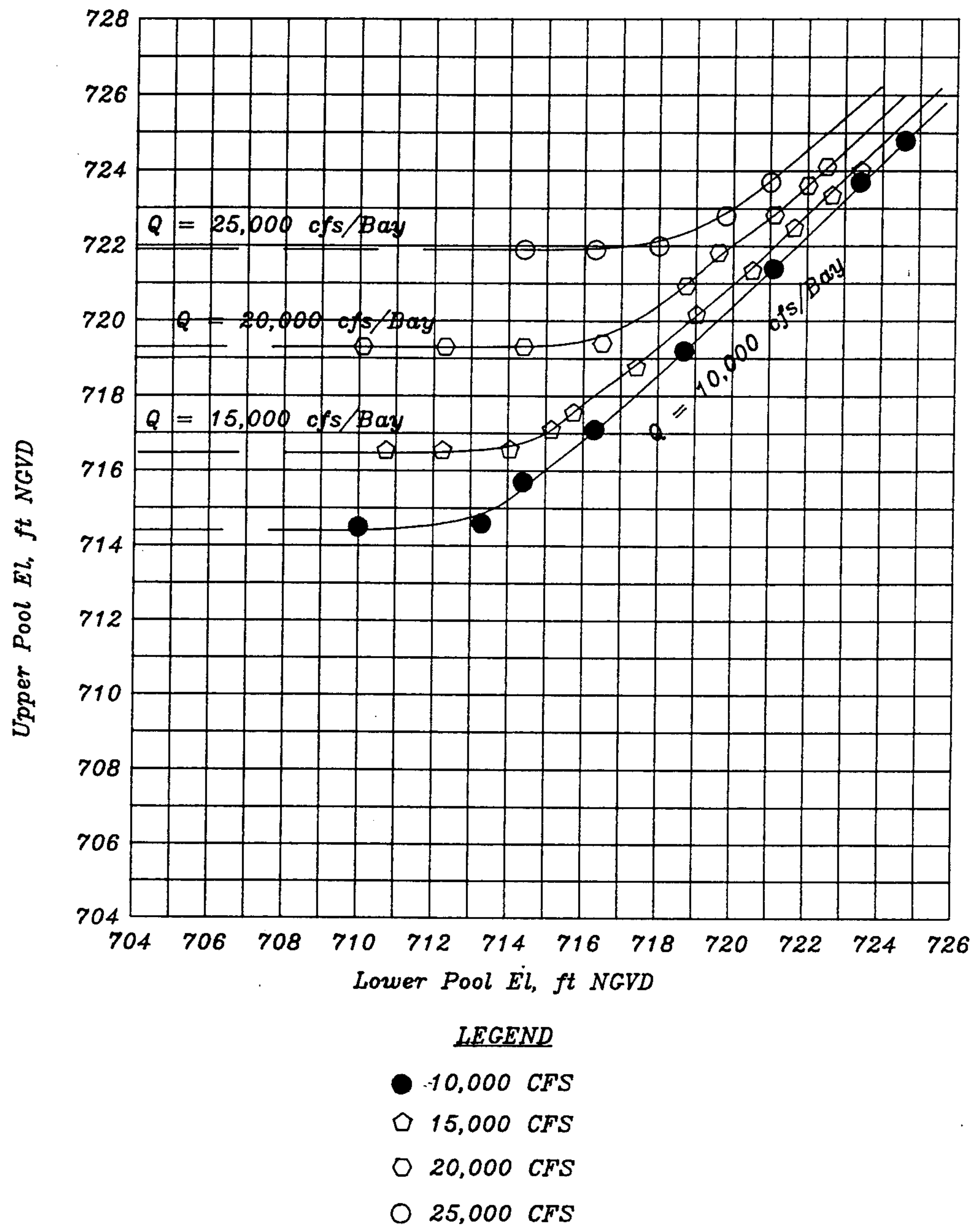
DISCHARGE–HEAD RELATIONSHIP
FOR FREE FLOW
HIGH GATE BAY

CREST ELEVATION 714.0

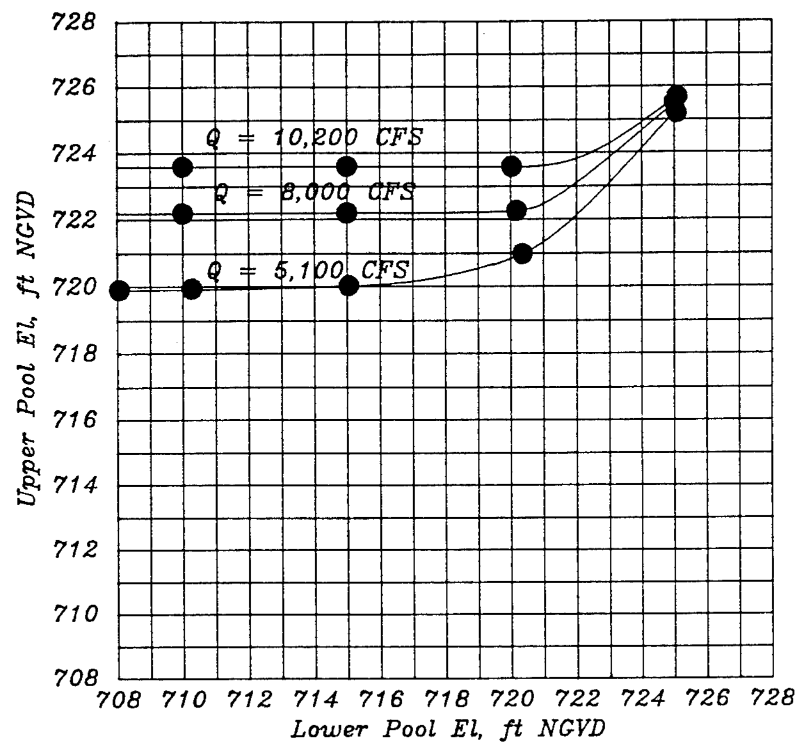


CALIBRATION DATA FOR UNCONTROLLED FLOW, LOW GATE BAY

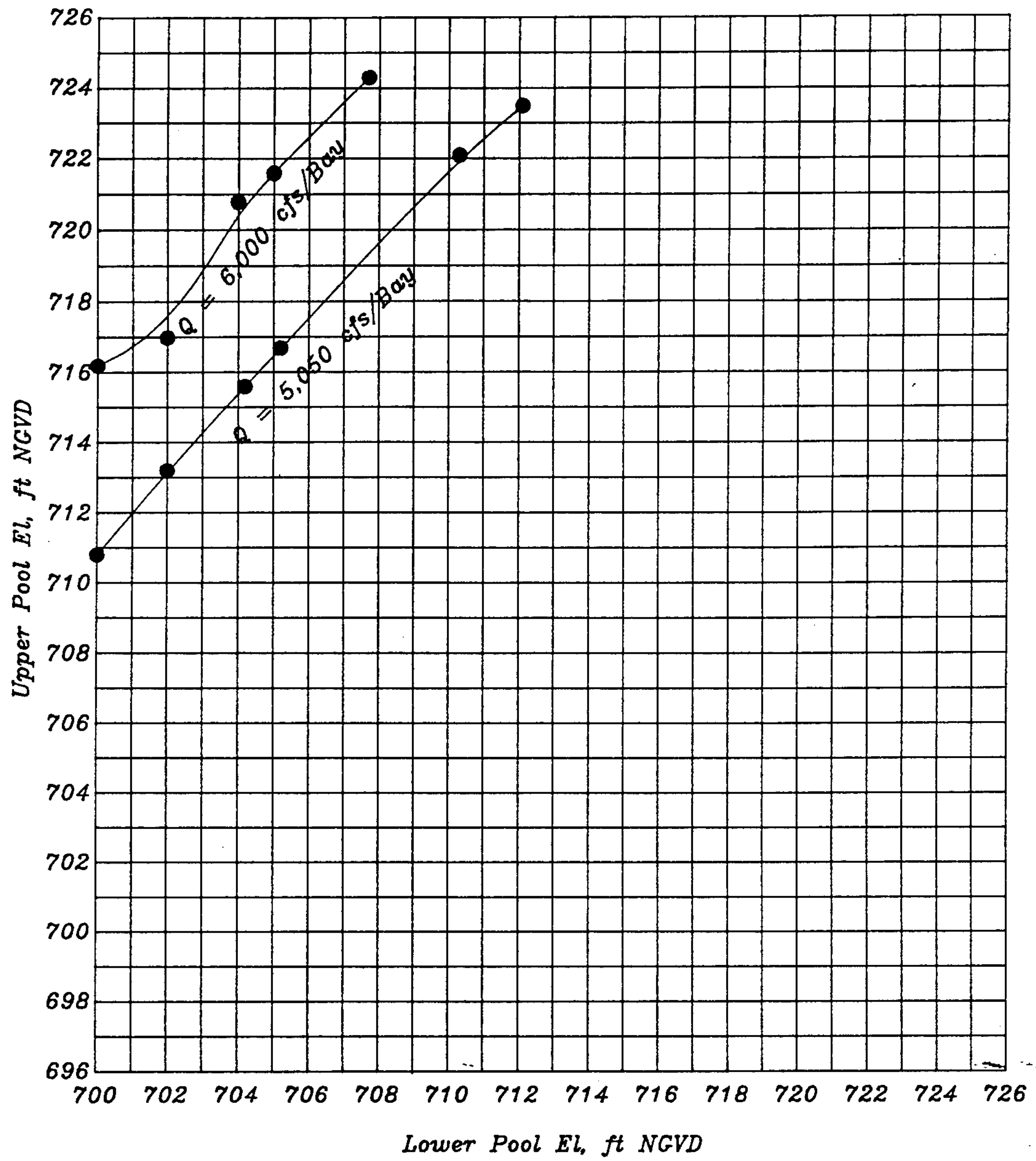
CREST ELEVATION 696.7



CALIBRATION DATA FOR UNCONTROLLED FLOW, LOW GATE BAY
CREST ELEVATION 704.7

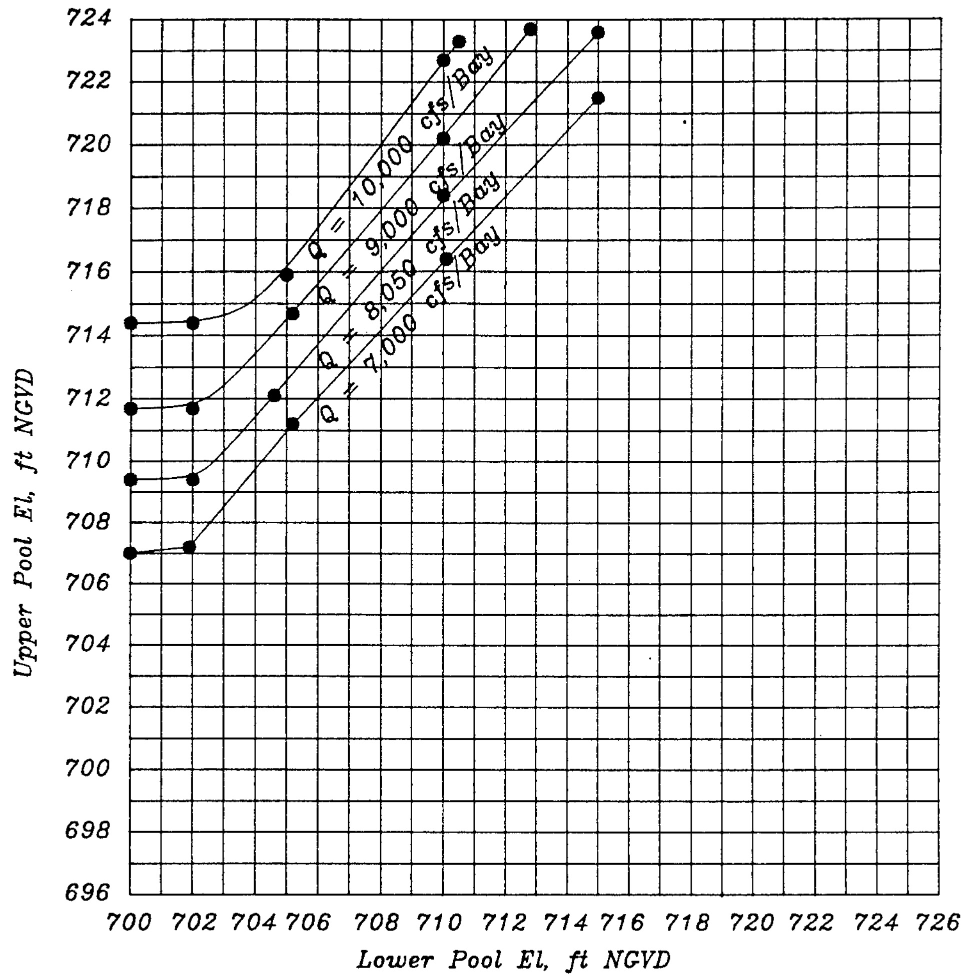


CALIBRATION DATA FOR UNCONTROLLED FLOW, HIGH GATE BAY
CREST ELEVATION 714.0

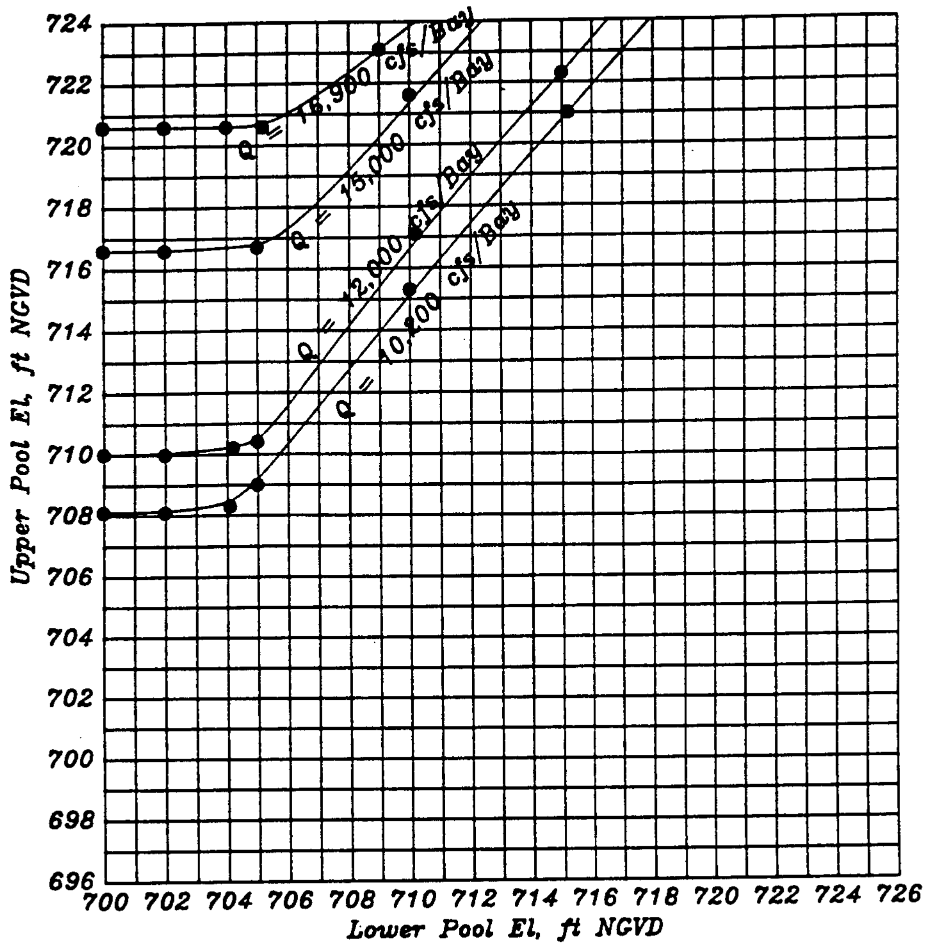


CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY

CREST ELEVATION 696.7
GATE OPENING 2.0 FT

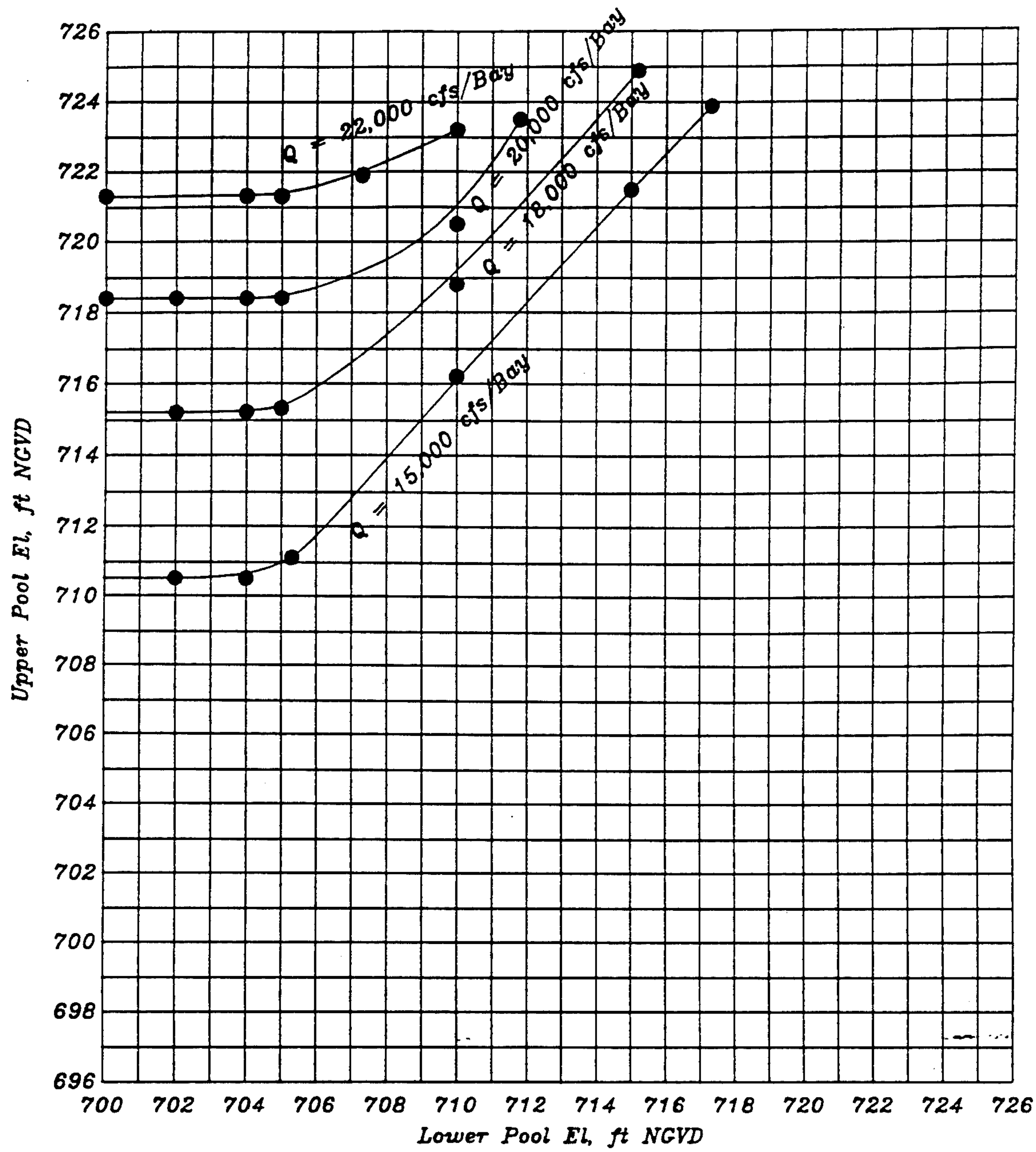


CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY
CREST ELEVATION 696.7
GATE OPENING 4.0



CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY

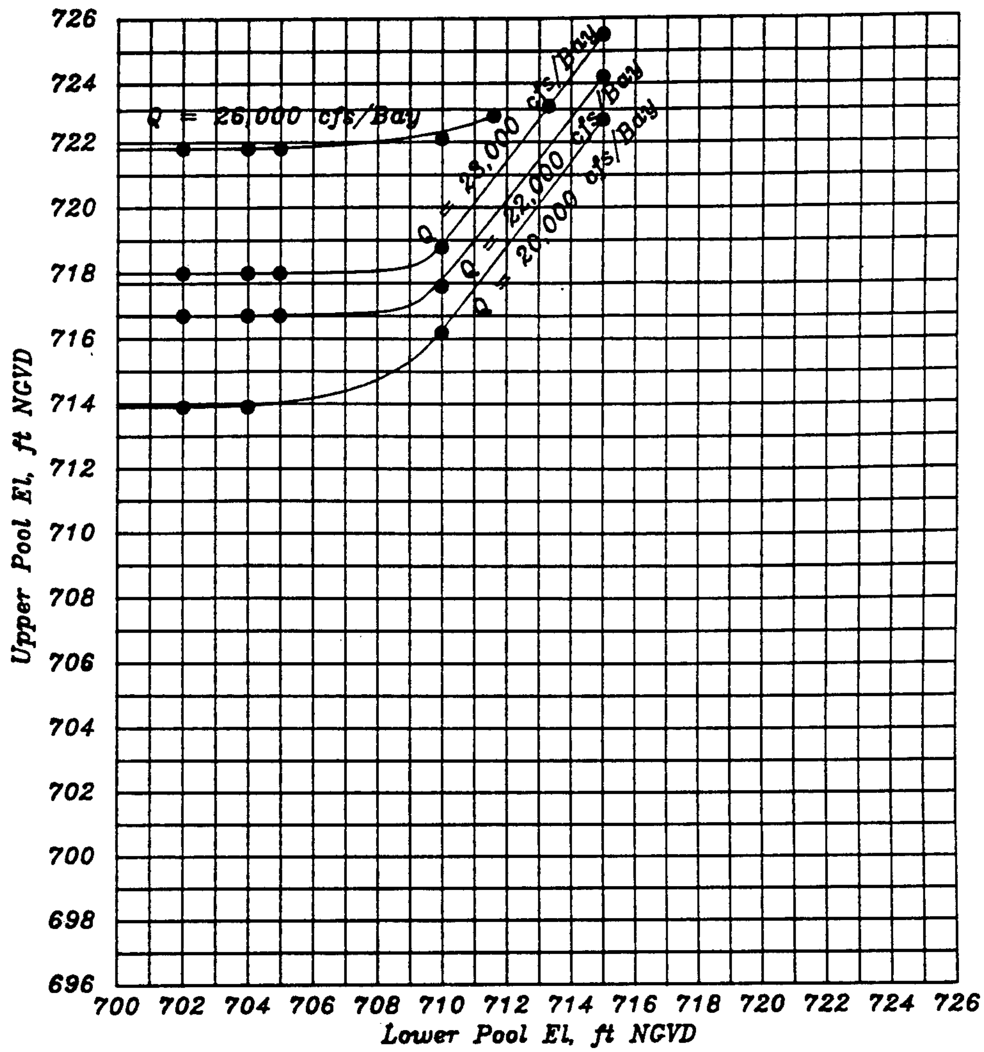
CREST ELEVATION 696.7
GATE OPENING 6.0 FT



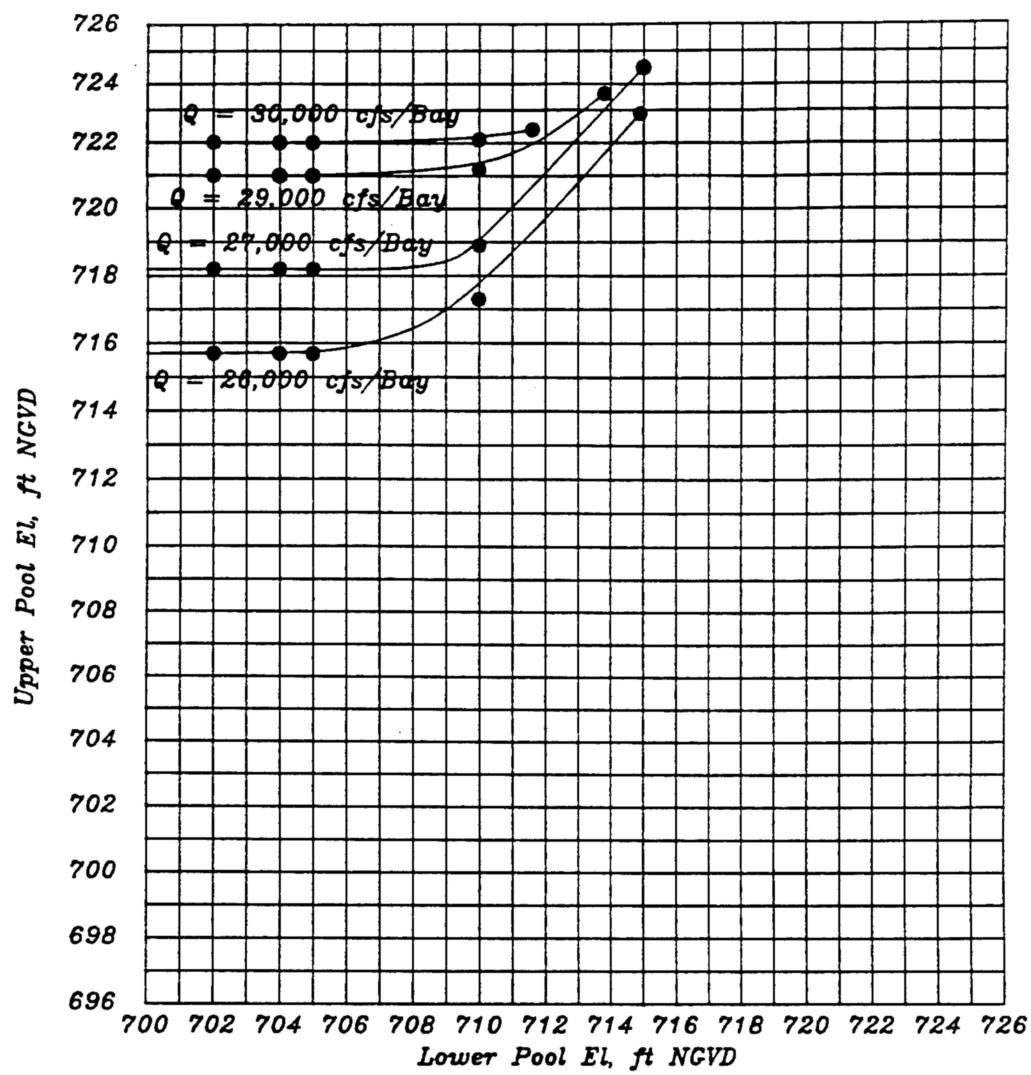
CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY

CREST ELEVATION 696.7

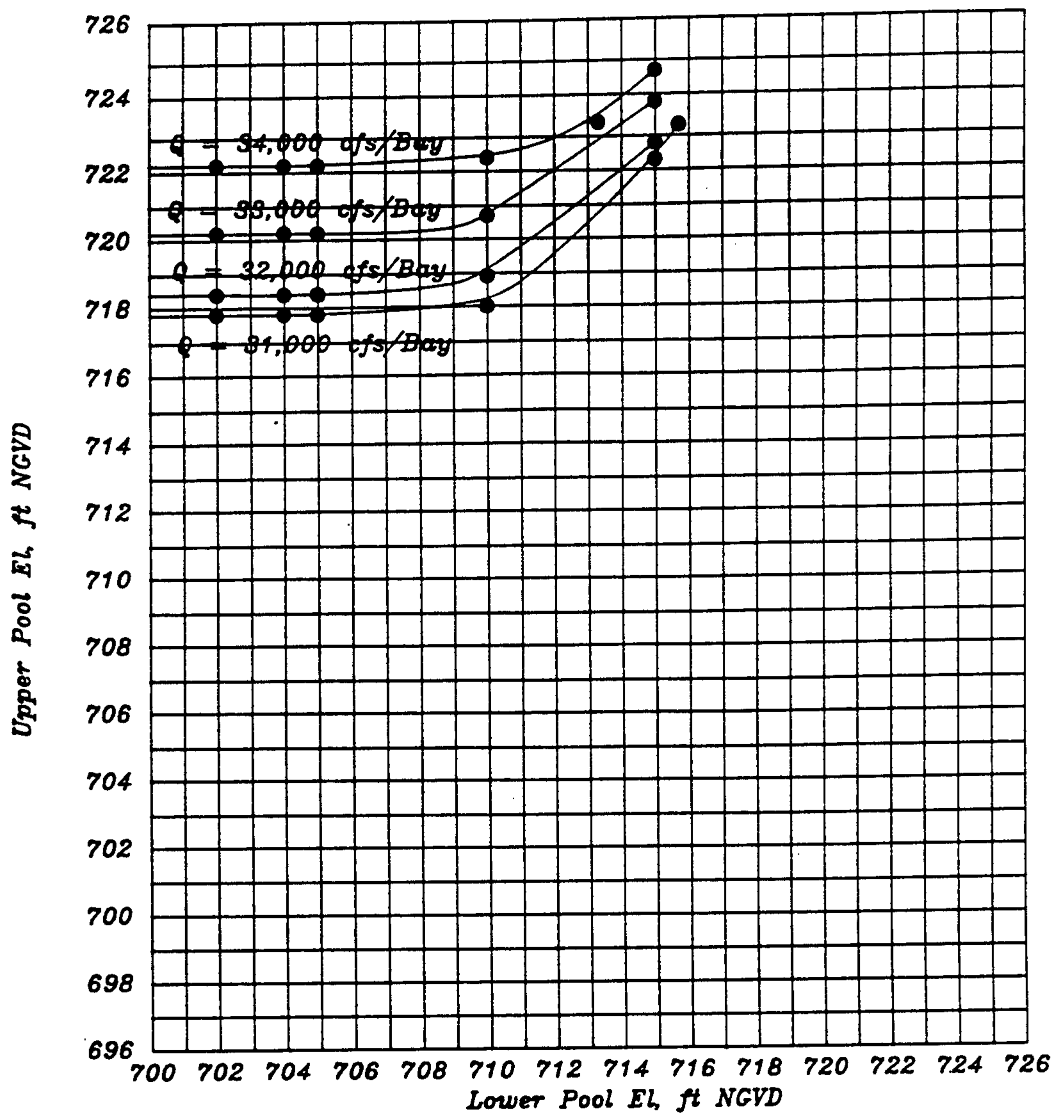
GATE OPENING 8.0 FT



CALIBRATION DATA FOR CONTROLLED
FLOW, LOW GATE BAY
CREST ELEVATION 696.7
GATE OPENING 10.0 FT



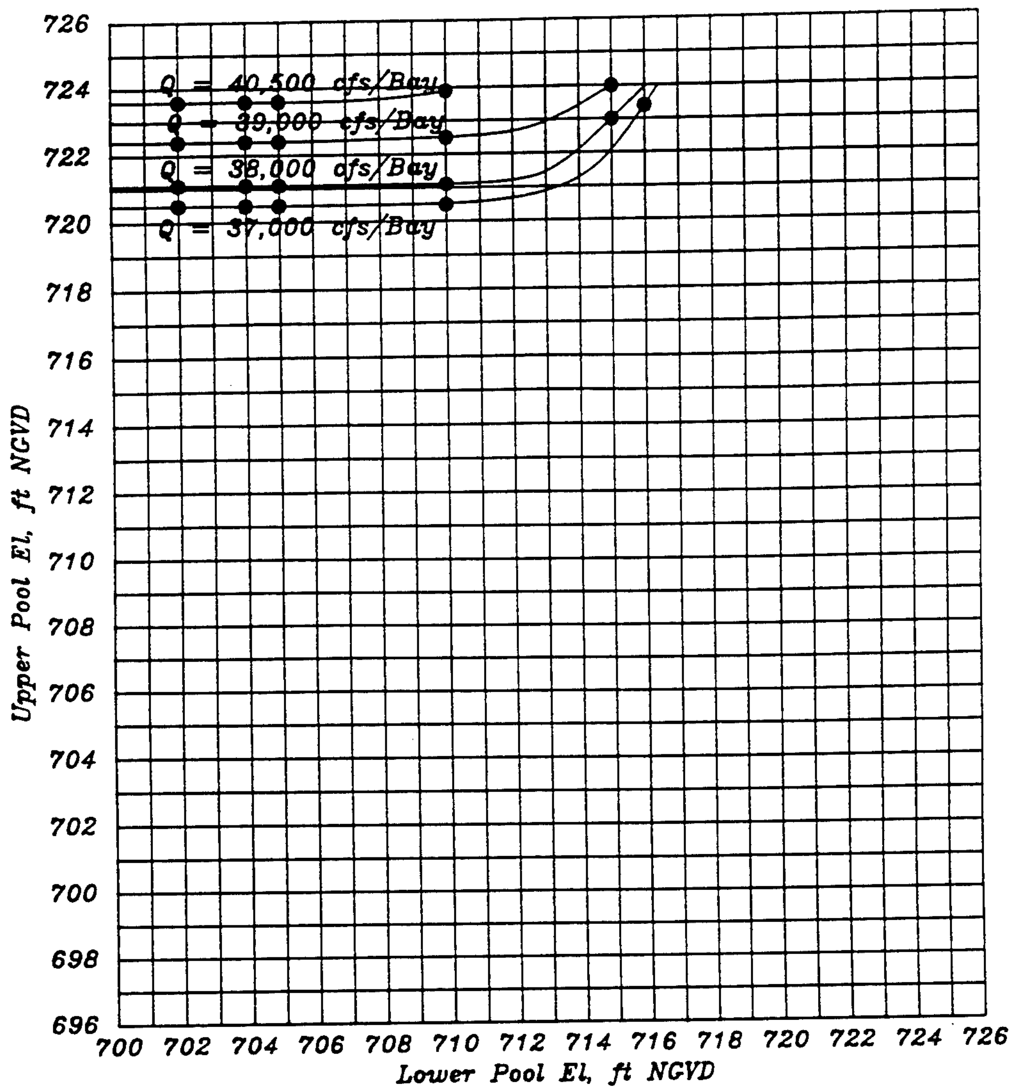
CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY
CREST ELEVATION 696.7
GATE OPENING 12.0 FT



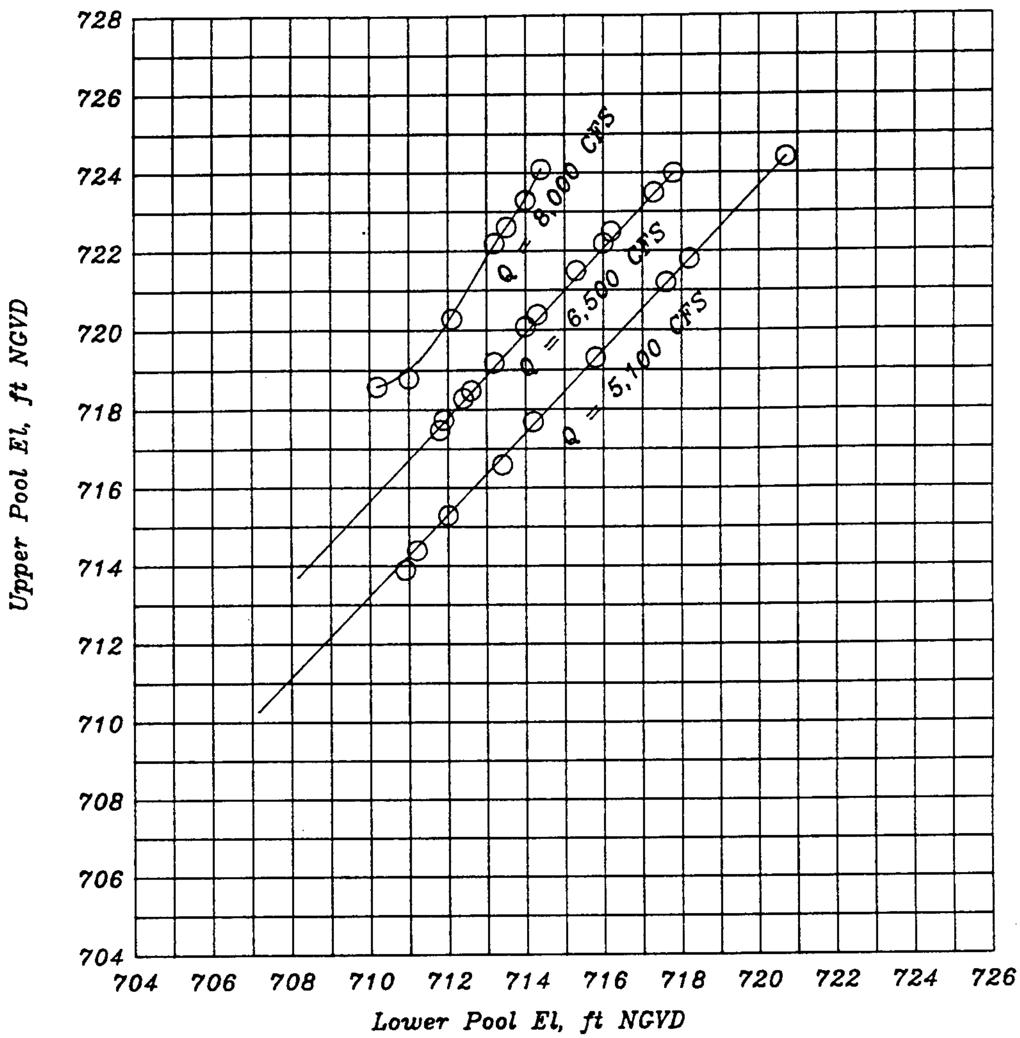
CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY

CREST ELEVATION 696.7

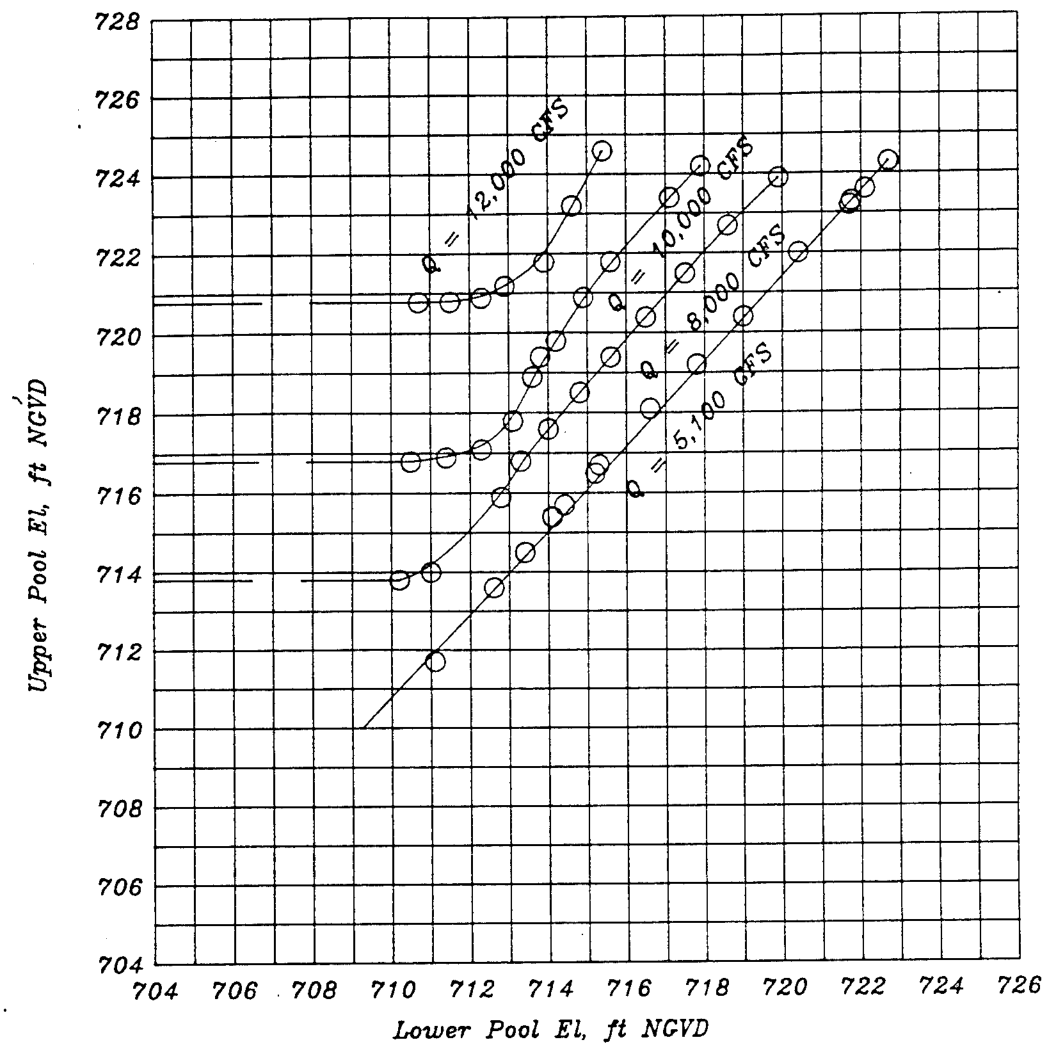
GATE OPENING 14.0 FT



CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY
CREST ELEVATION 696.7
GATE OPENING 16.0 FT



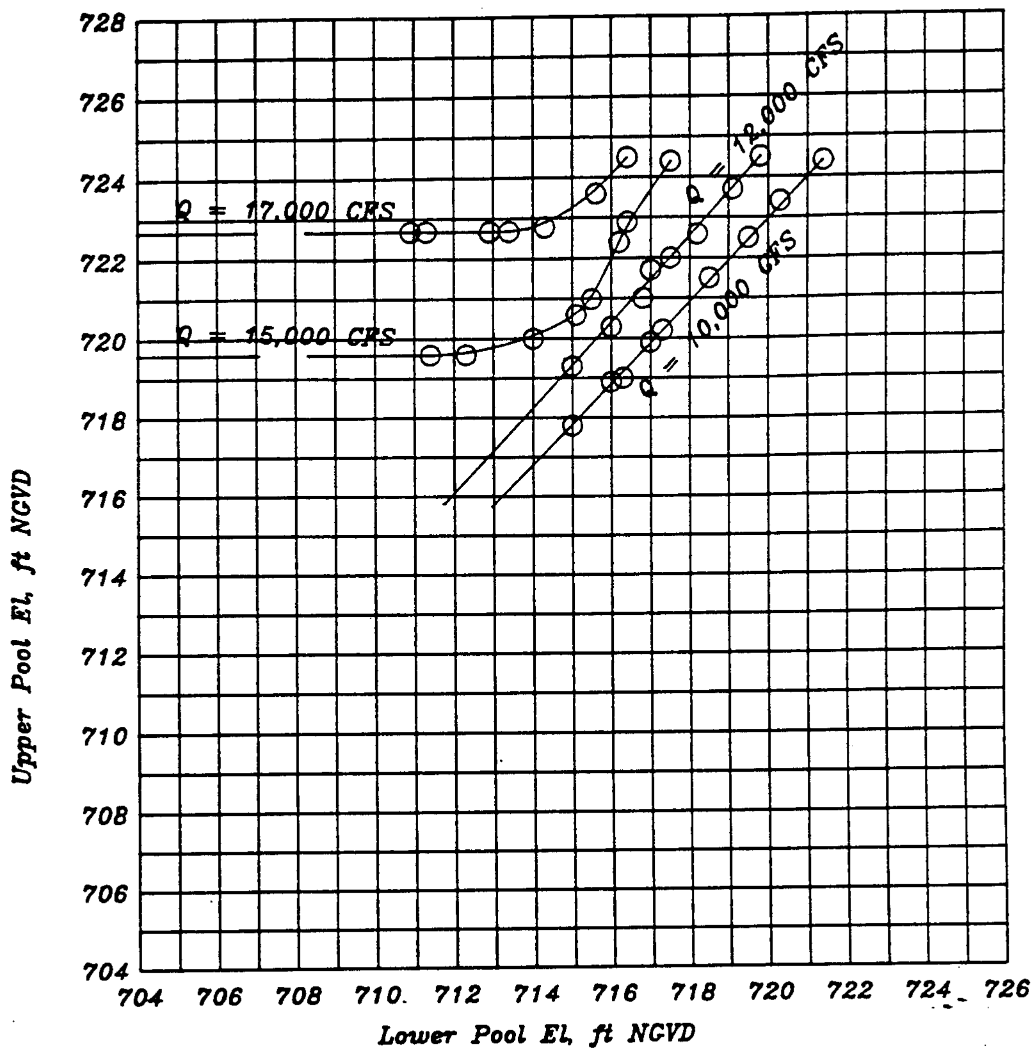
CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY
CREST ELEVATION 704.7
GATE OPENING 4.0



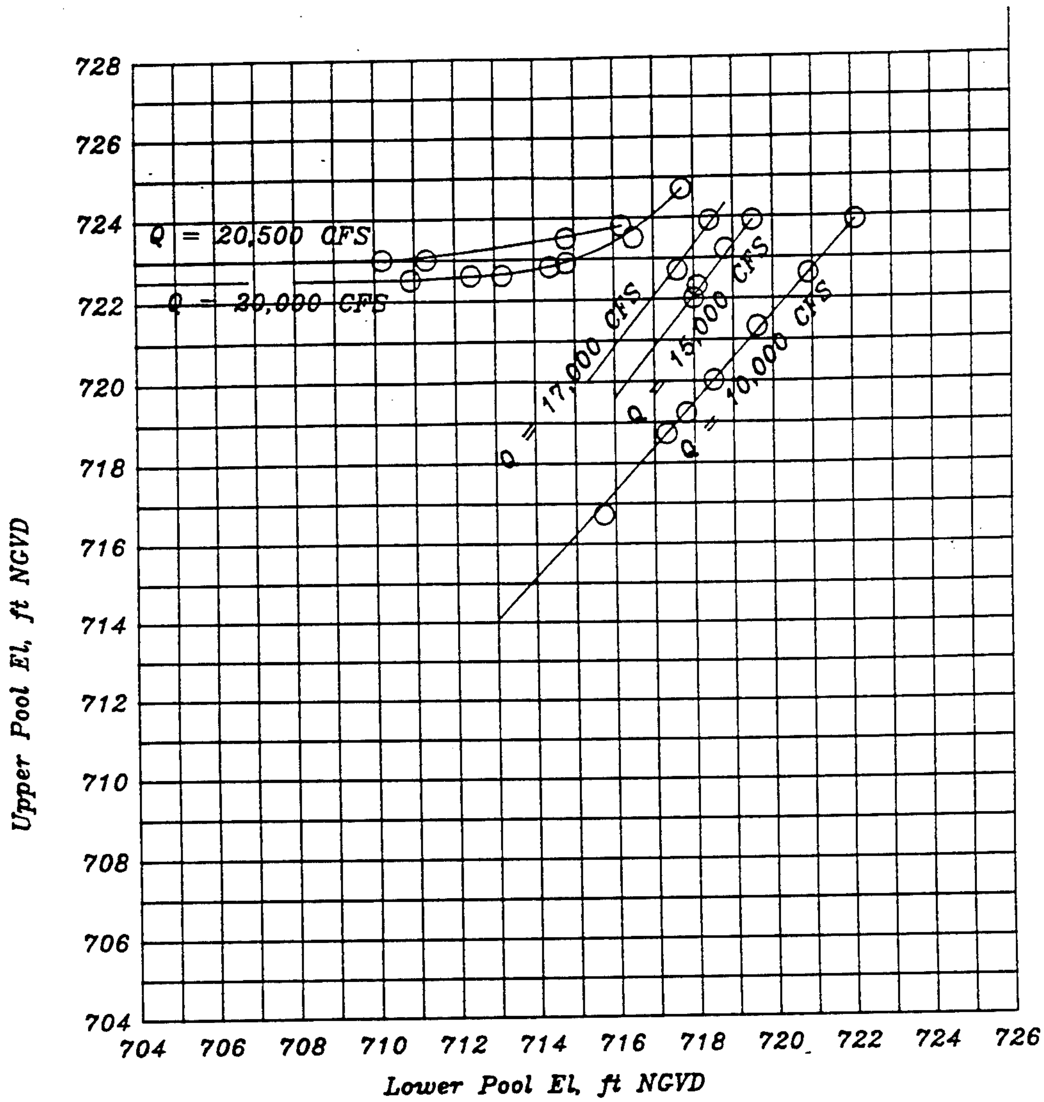
CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY

CREST ELEVATION 704.7

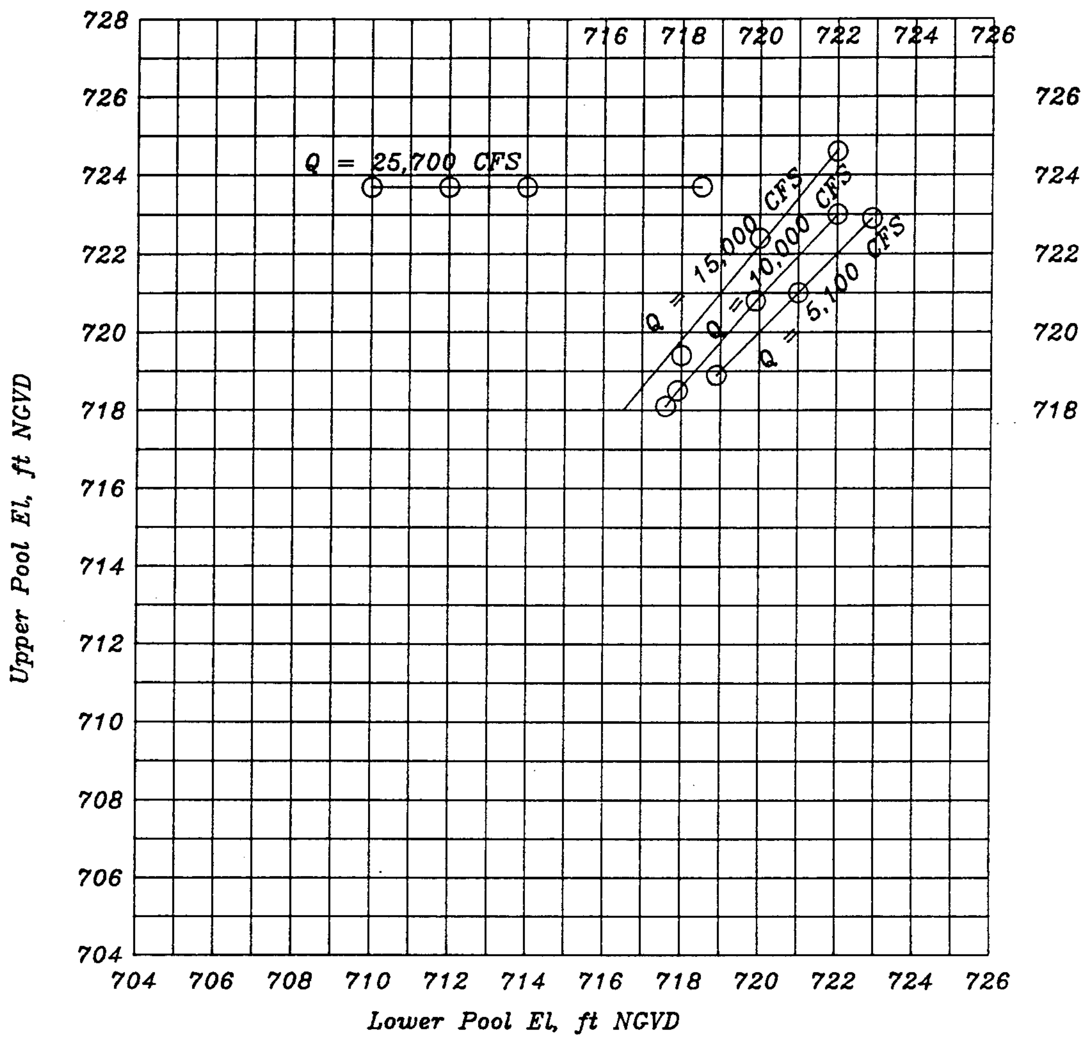
GATE OPENING 6.0 FT



CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY
CREST ELEVATION 704.7
GATE OPENING 8.0 FT



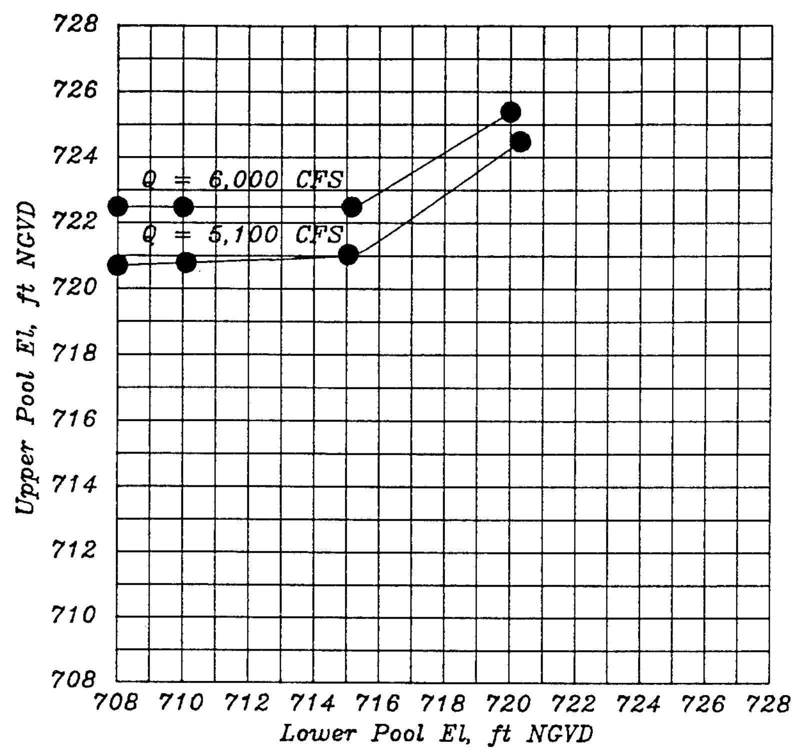
CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY
CREST ELEVATION 704.7
GATE OPENING 10.0 FT



CALIBRATION DATA FOR CONTROLLED FLOW, LOW GATE BAY

CRTEST ELEVATION 704.7

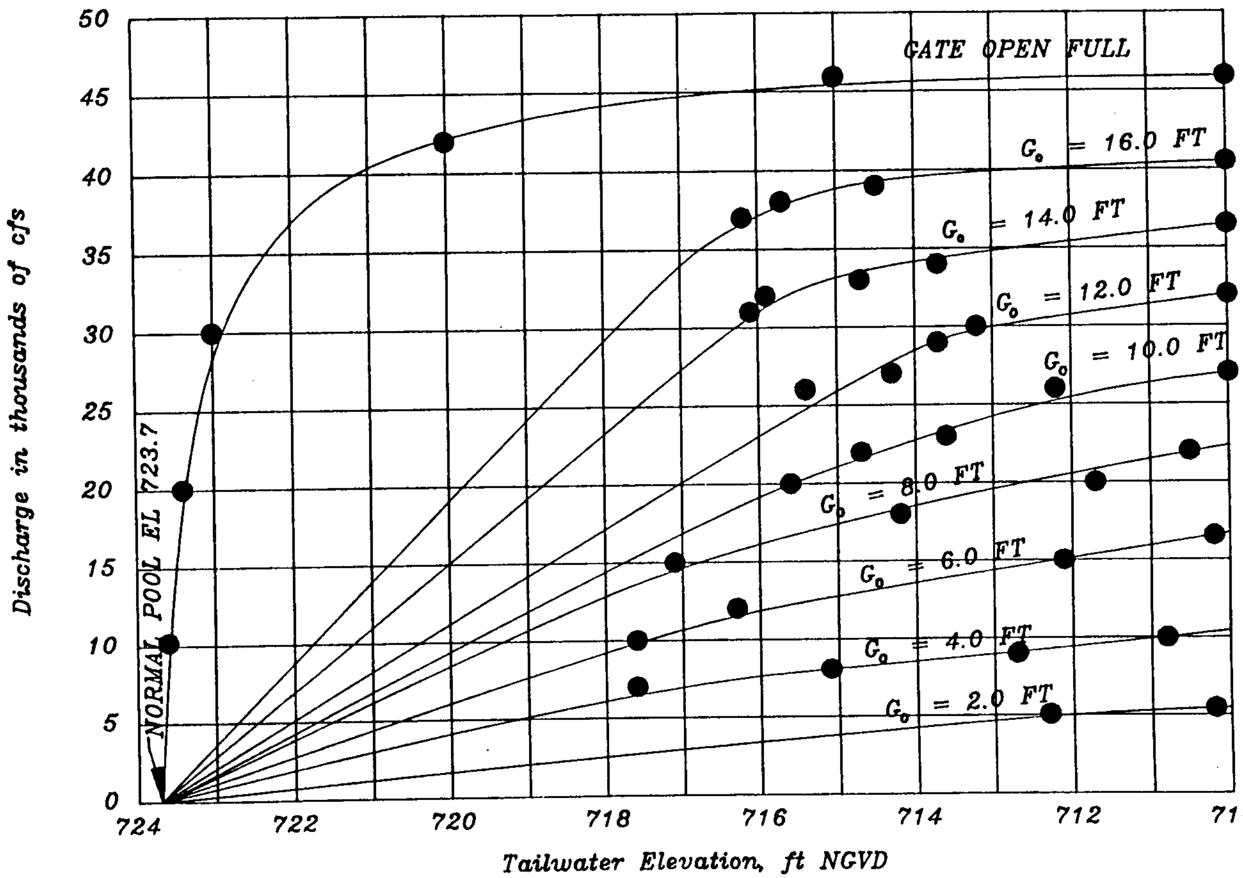
GATE OPENING 12.0 FT



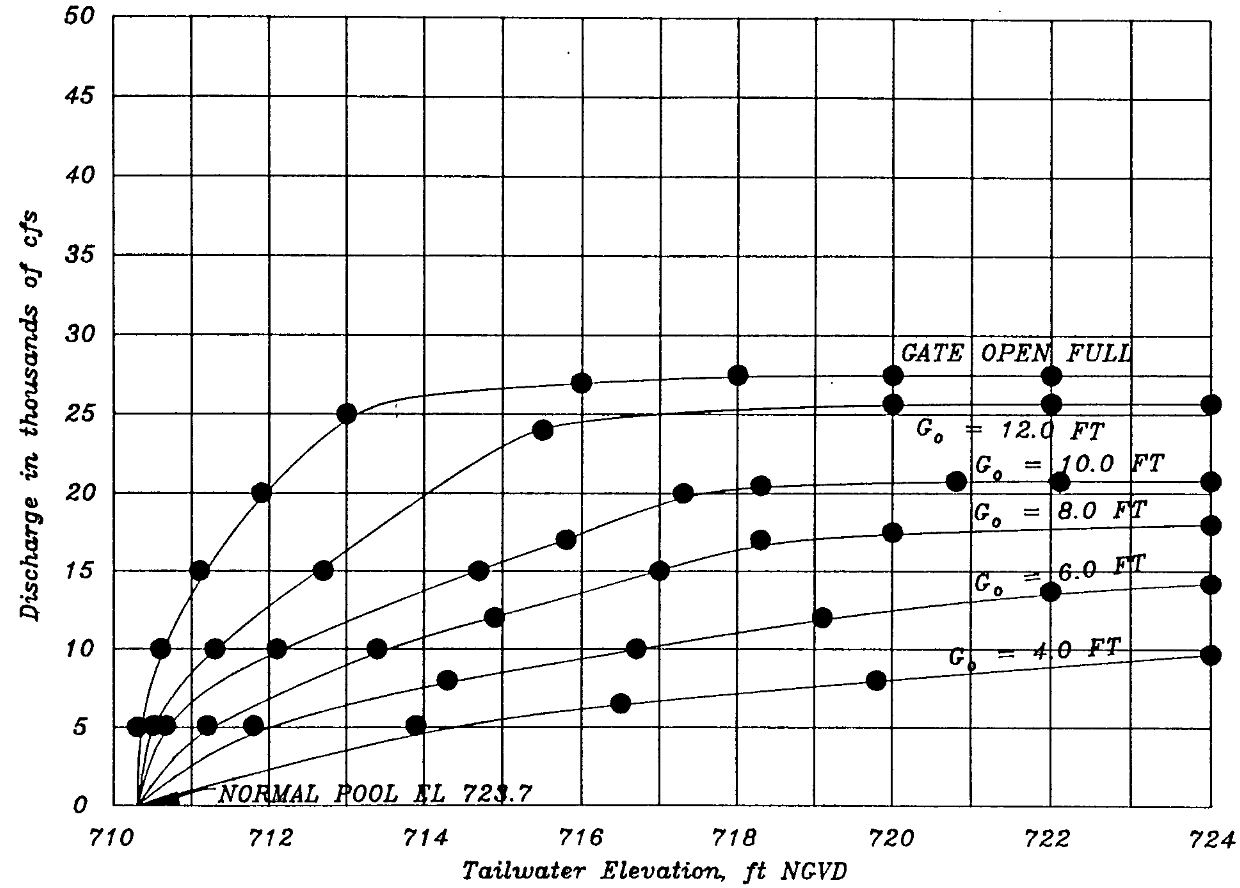
CALIBRATION DATA FOR CONTROLLED FLOW, HIGH GATE BAY

CREST ELEVATION 714.0

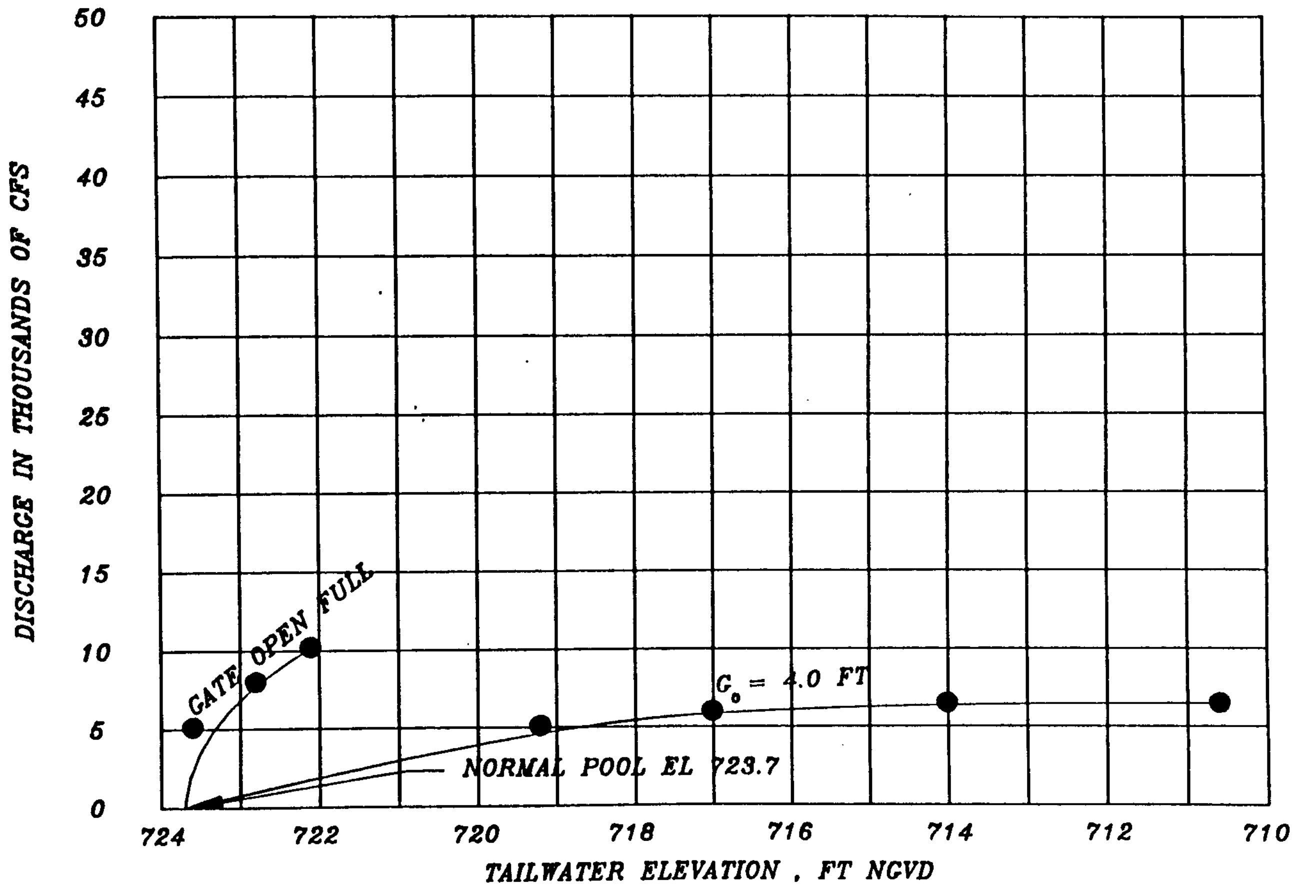
GATE OPENING 4.0 FT



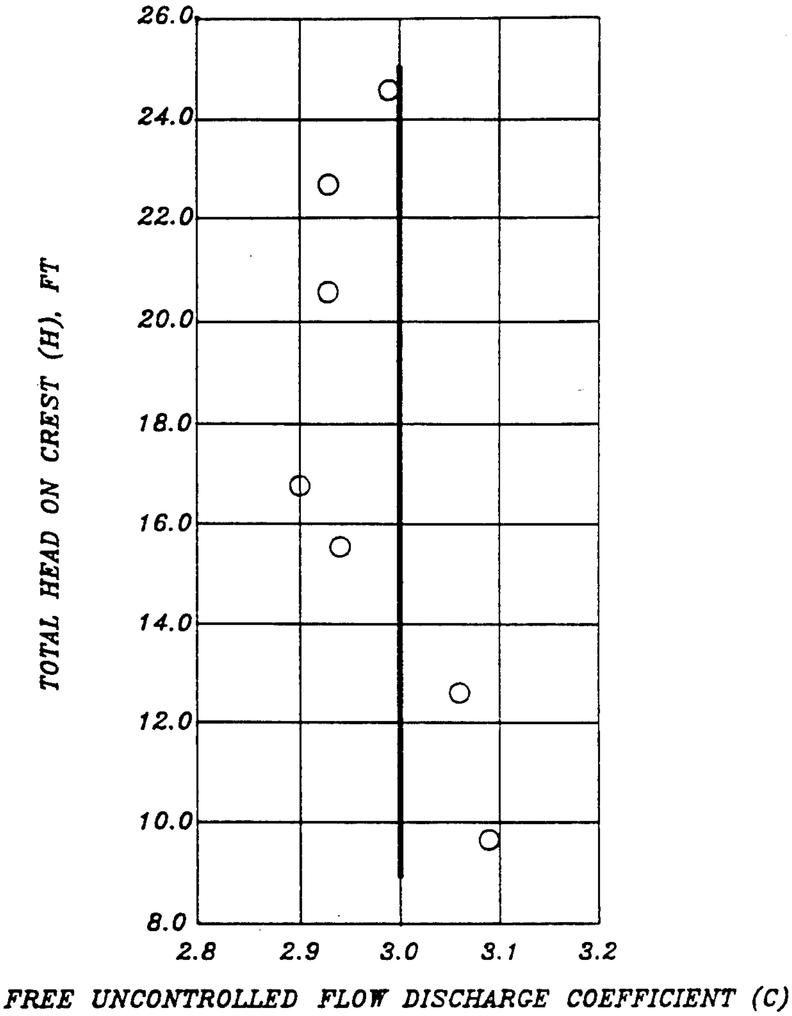
TAILWATER EFFECT
ON DISCHARGE
CREST EL 696.7
POOL EL 723.7



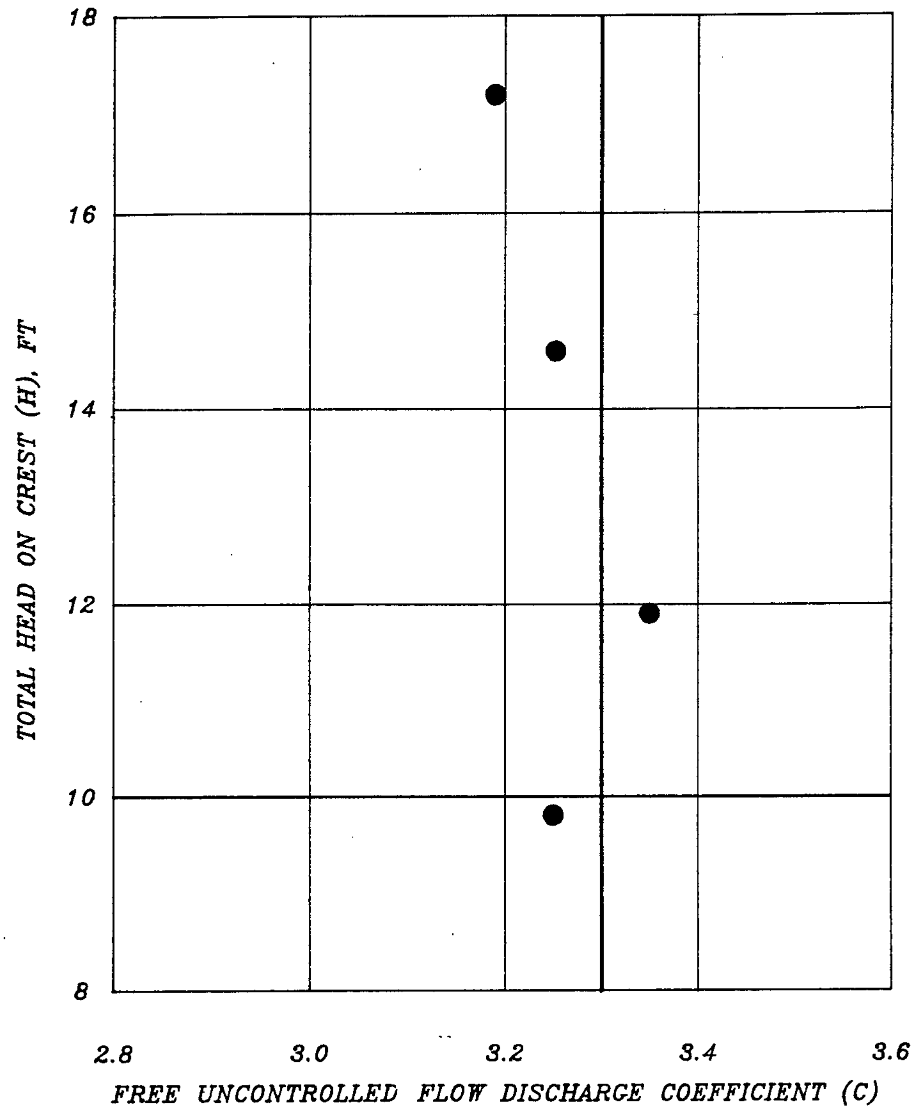
TAILWATER EFFECT
ON DISCHARGE
CREST EL 704.7
POOL EL 723.7



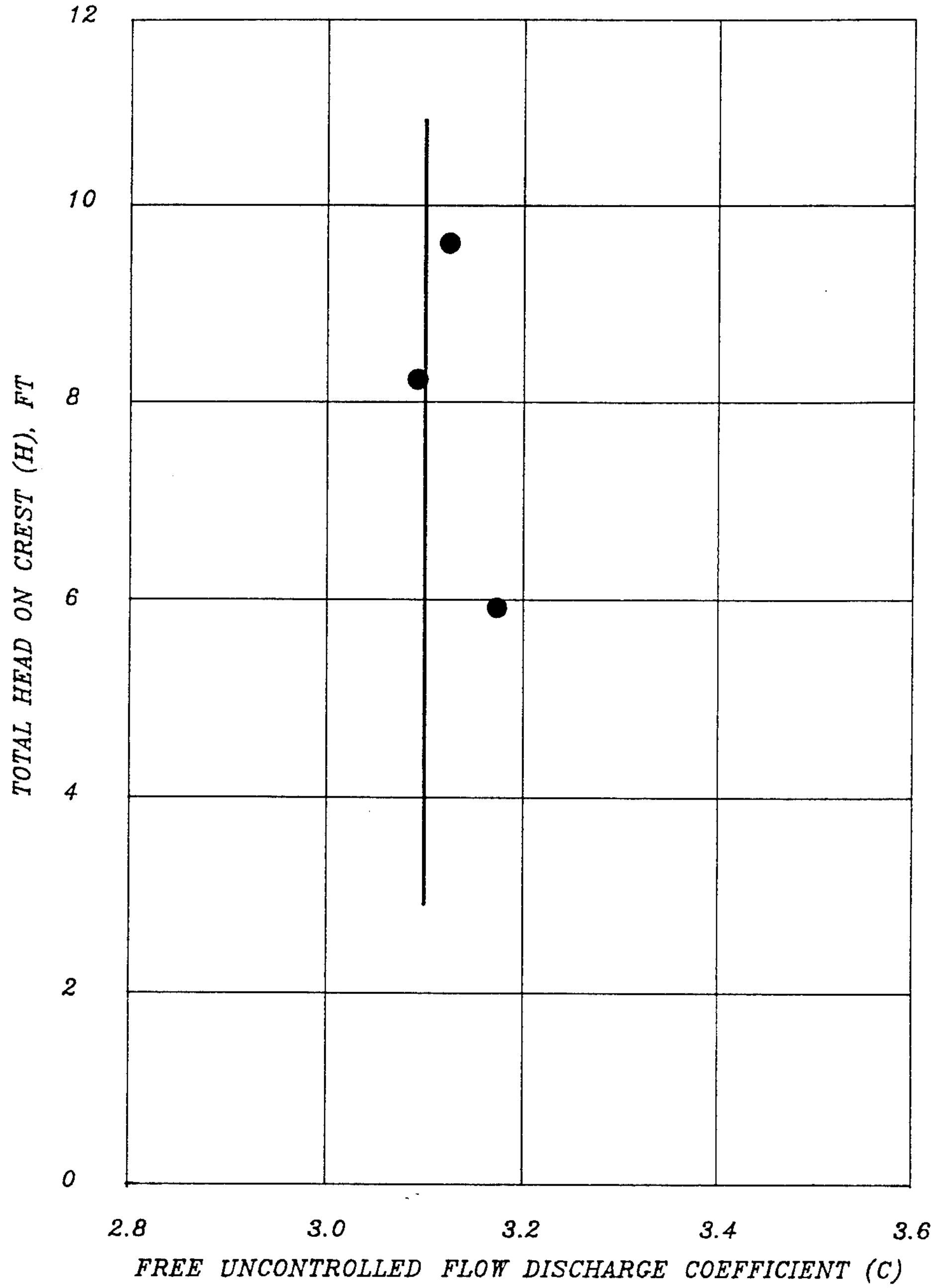
TAILWATER EFFECT
ON DISCHARGE
CREST ELEVATION 714.0
POOL EL 723.7



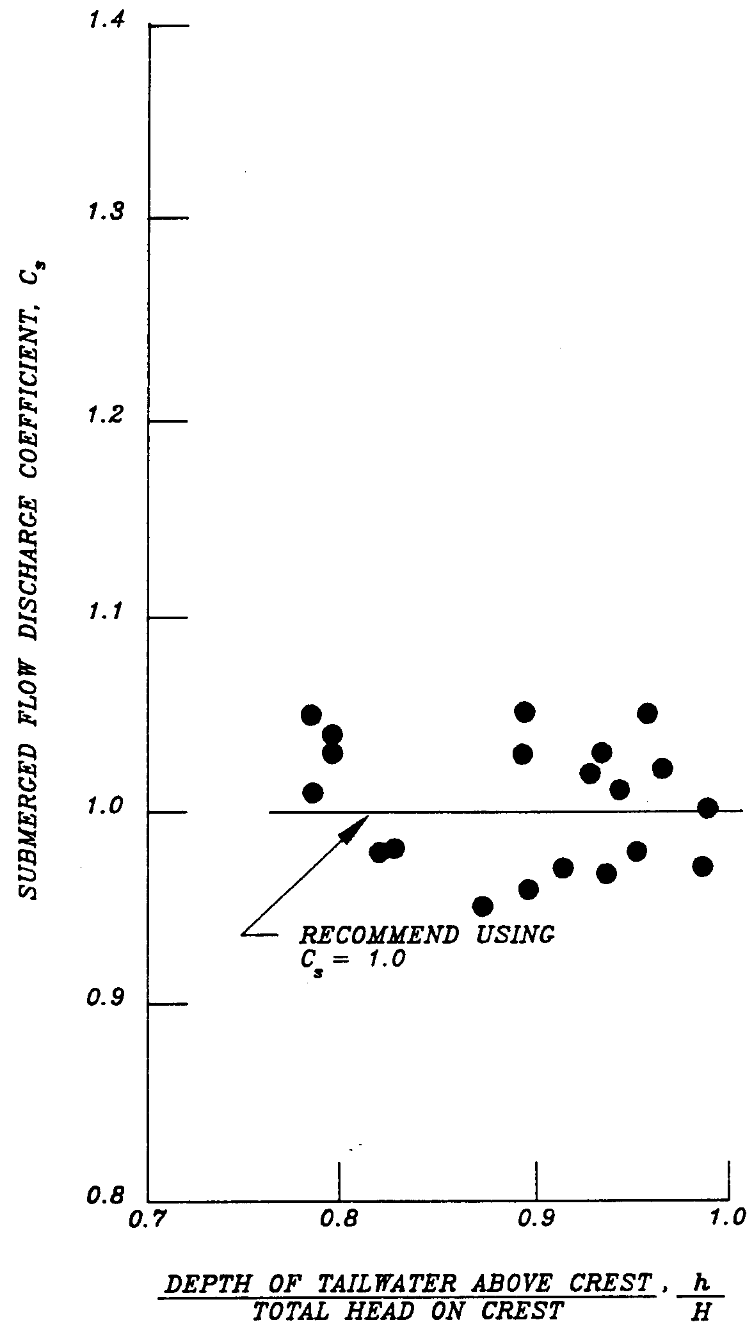
DISCHARGE COEFFICIENTS
FOR FREE UNCONTROLLED FLOW
LOW GATE BAY
CREST ELEVATION 696.7



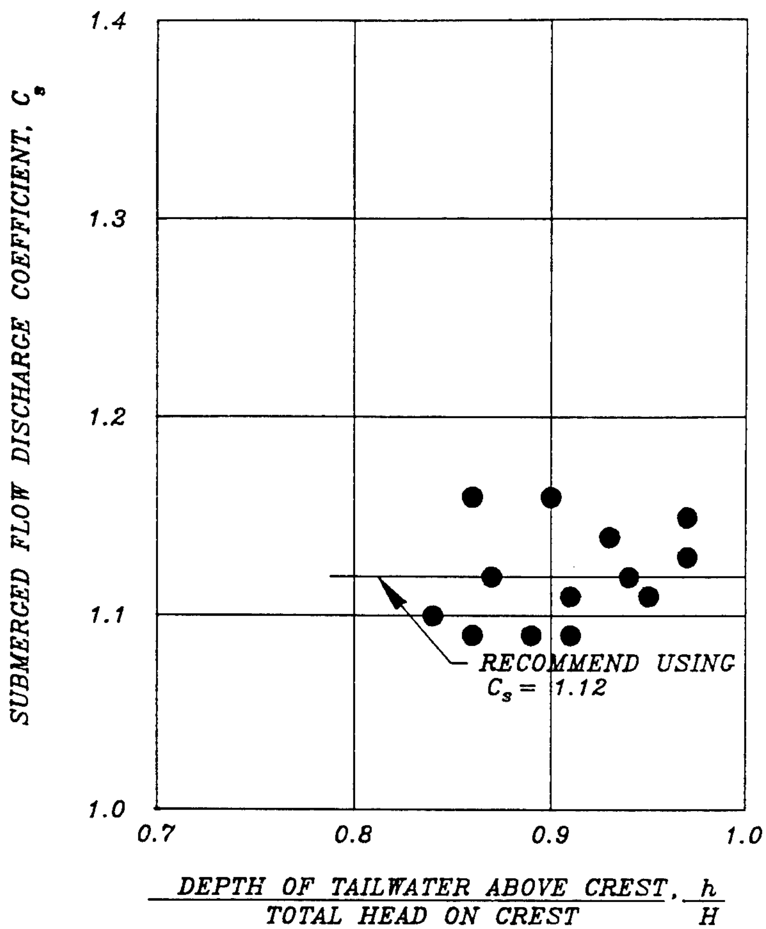
DISCHARGE COEFFICIENTS FOR
FREE UNCONTROLLED FLOW
CREST ELEVATION 704.7



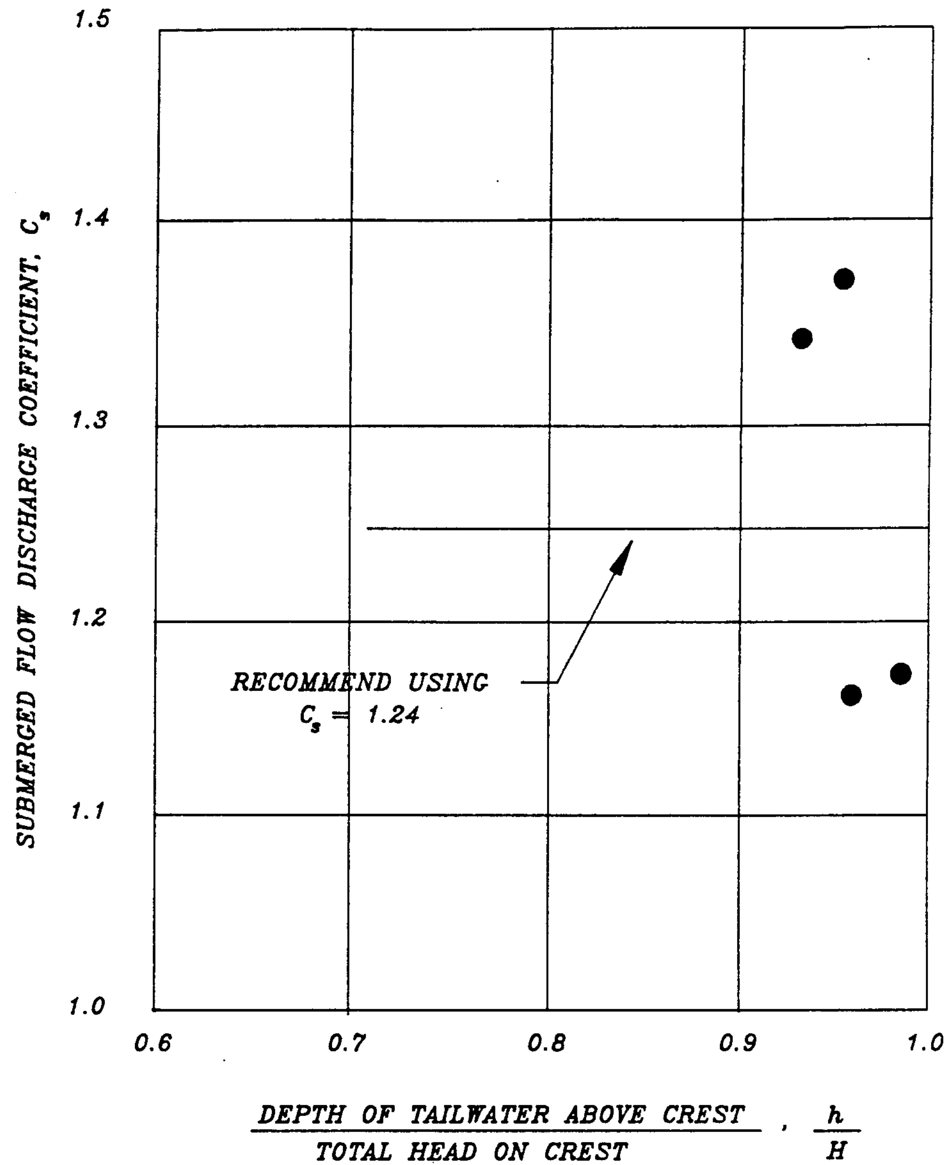
DISCHARGE COEFFICIENTS FOR
FREE UNCONTROLLED FLOW,
HIGH GATE BAY
CREST ELEVATION 714.0



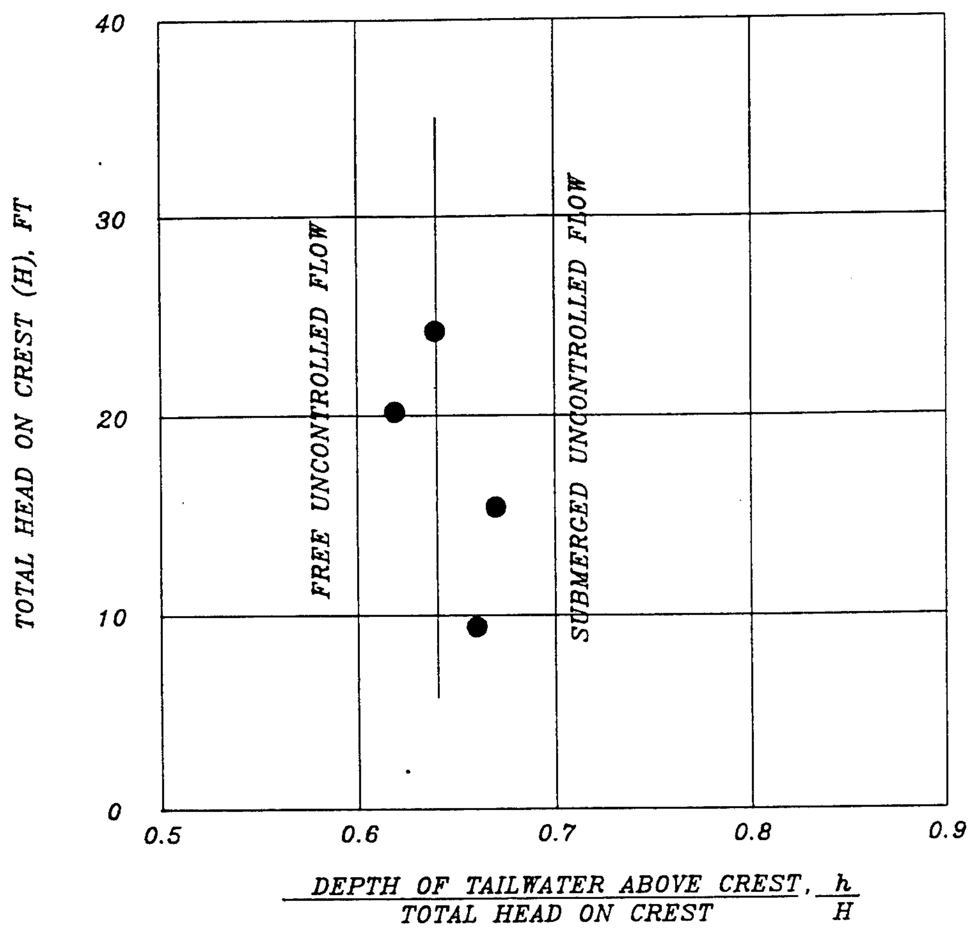
DISCHARGE COEFFICIENTS FOR
SUBMERGED UNCONTROLLED FLOW
LOW GATE BAYS
CREST ELEVATION 696.7



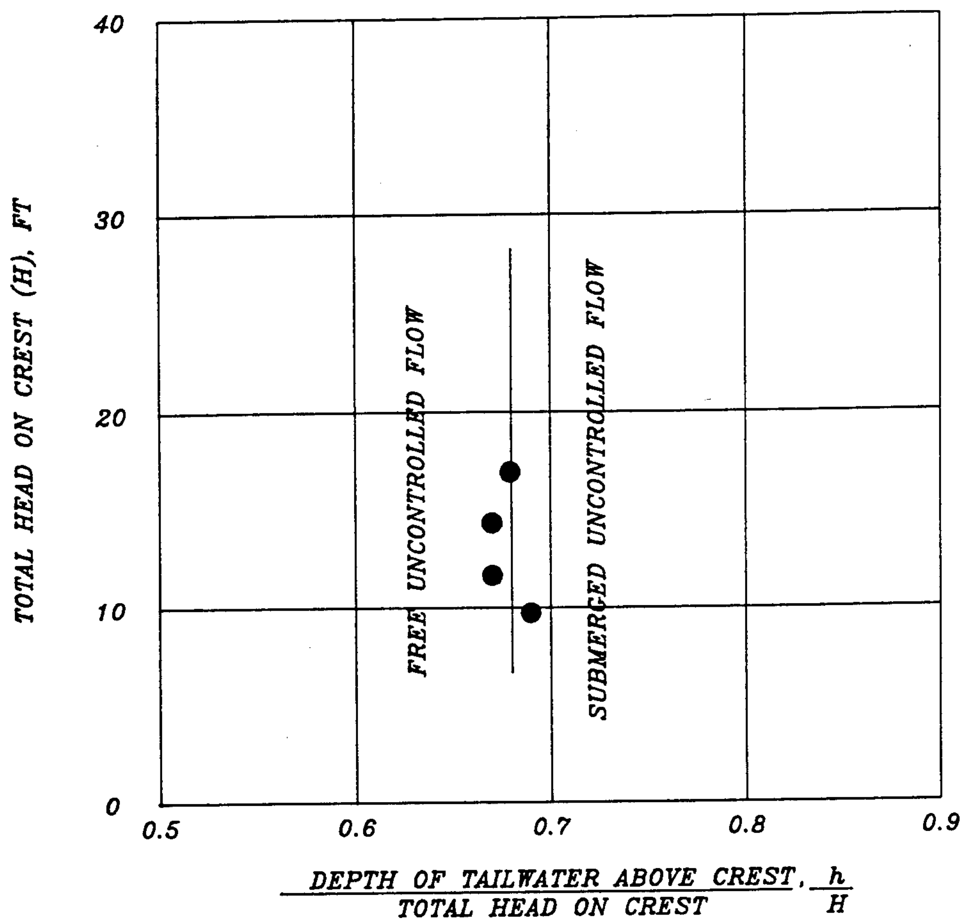
DISCHARGE COEFFICIENTS FOR
SUBMERGED UNCONTROLLED FLOW
CREST ELEVATION 704.7



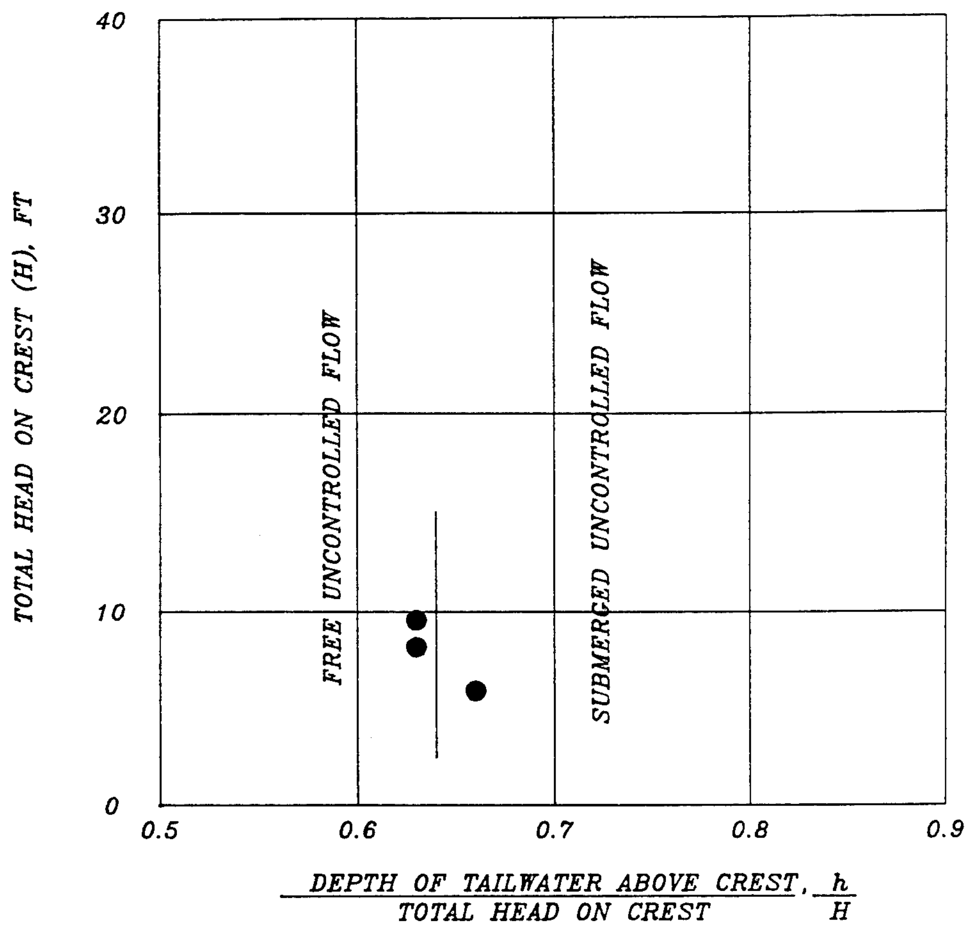
DISCHARGE COEFFICIENT FOR
SUBMERGED UNCONTROLLED FLOW,
HIGH GATE BAY
CREST ELEVATION 714.0



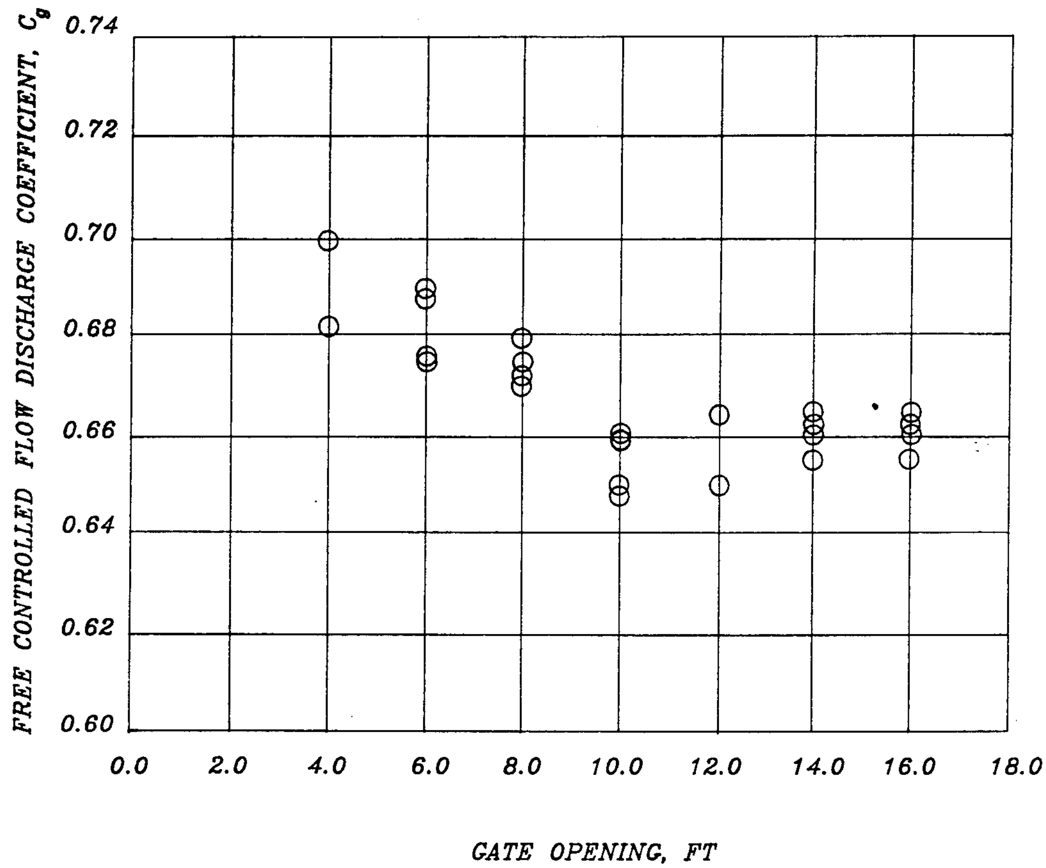
UNCONTROLLED FLOW REGIMES
CREST ELEVATION 696.7



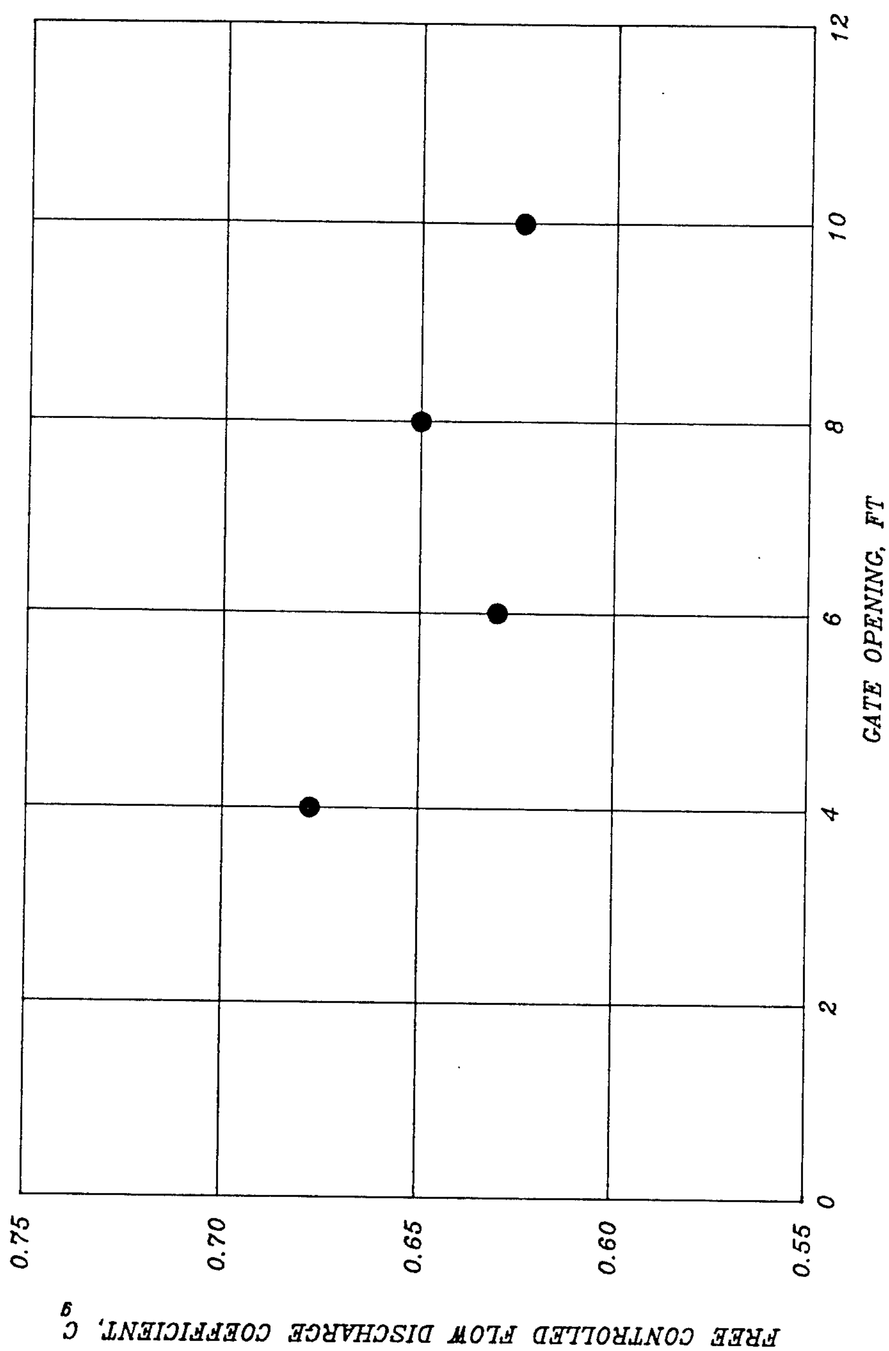
UNCONTROLLED FLOW REGIMES
CREST ELEVATION 704.7



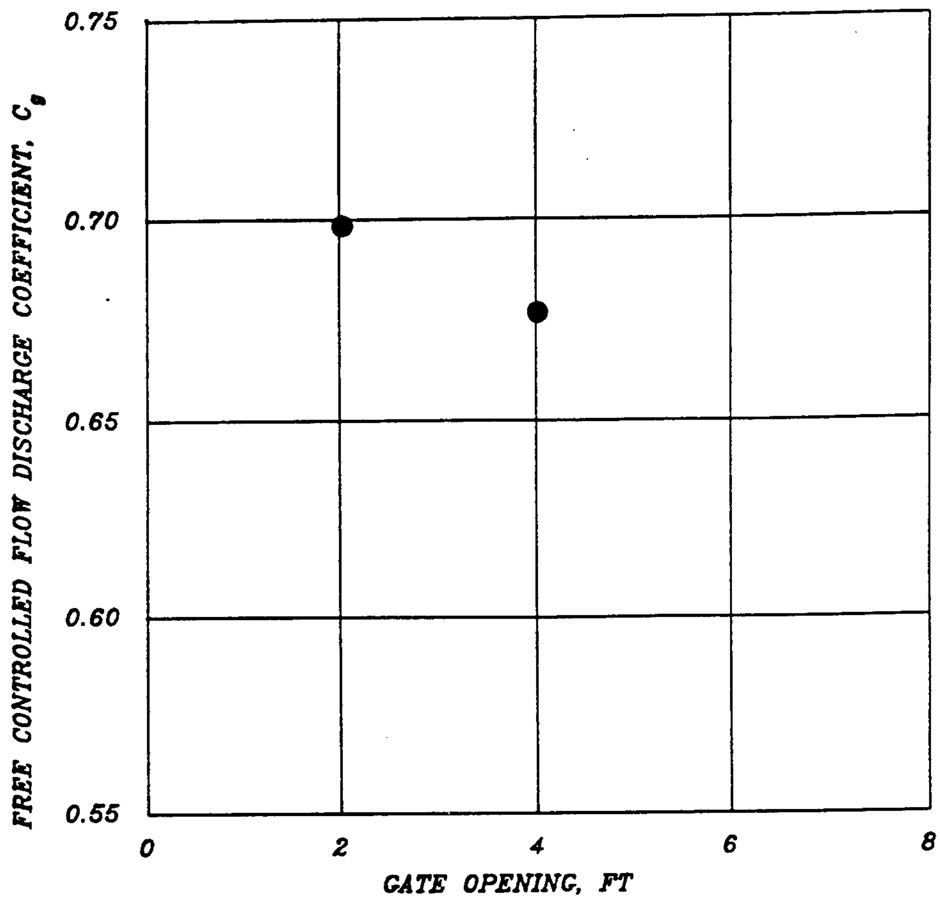
UNCONTROLLED FLOW REGIMES
CREST ELEVATION 714.0



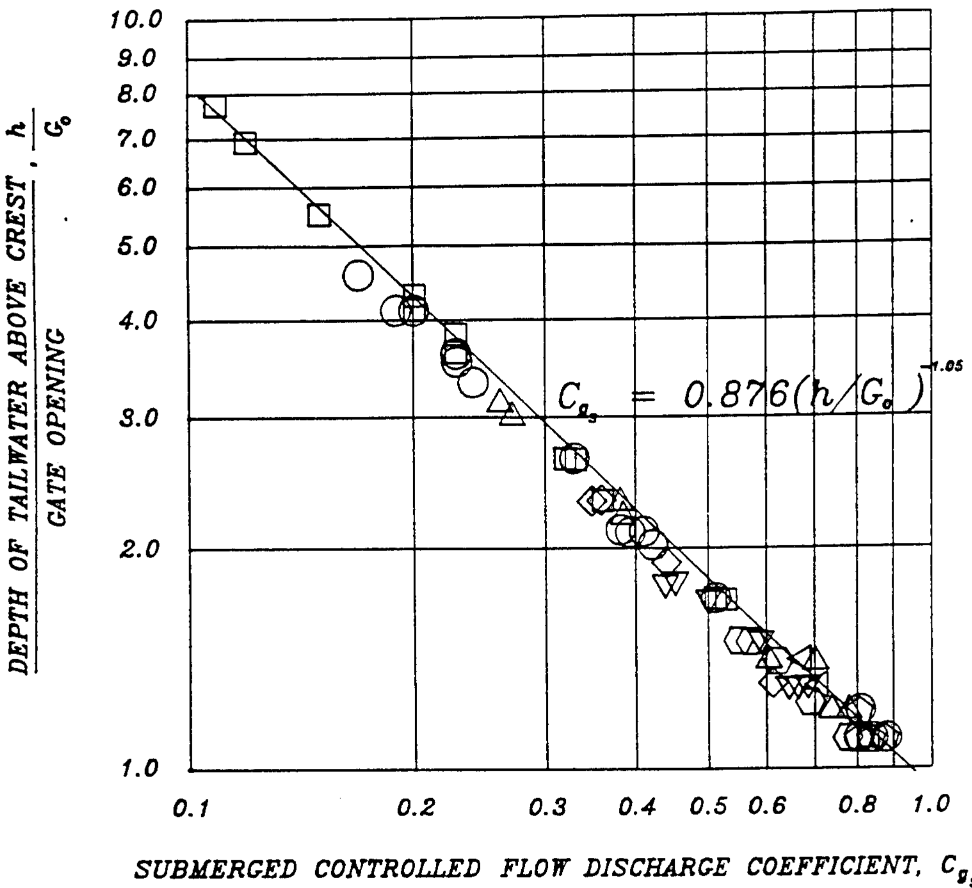
DISCHARGE COEFFICIENTS
FOR FREE CONTROLLED FLOW
LOW GATE BAYS
CREST ELEVATION 696.7



DISCHARGE COEFFICIENTS FOR
FREE CONTROLLED FLOW
CREST ELEVATION 704.7



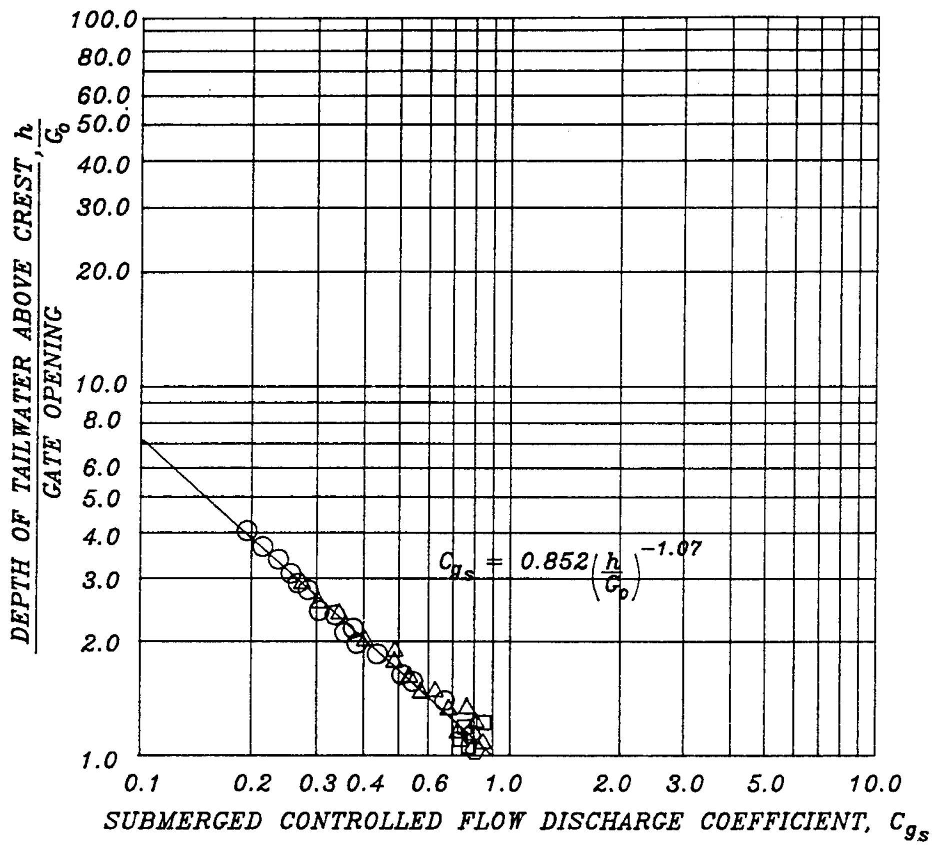
DISCHARGE COEFFICIENTS FOR
FREE CONTROLLED FLOW
HIGH GATE BAY
CREST ELEVATION 714.0



LEGEND

SYMBOL	*GATE OPENING FT*
□	2.0
○	4.0
△	6.0
◇	8.0
▽	10.0
⬡	12.0
◁	14.0
⬠	16.0

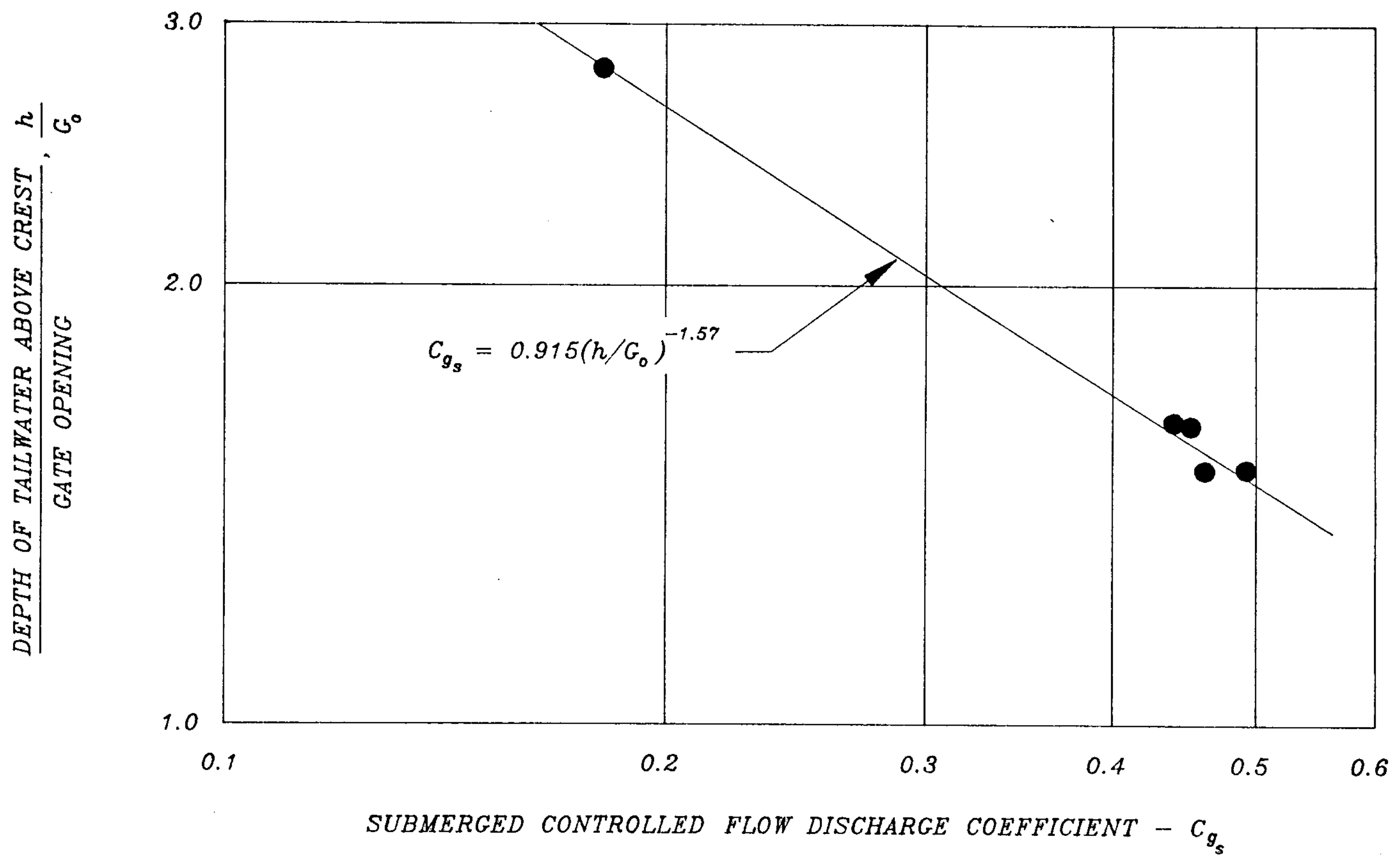
DISCHARGE COEFFICIENTS
FOR SUBMERGED CONTROLLED FLOW
LOW GATE BAYS
CREST ELEVATION 696.7



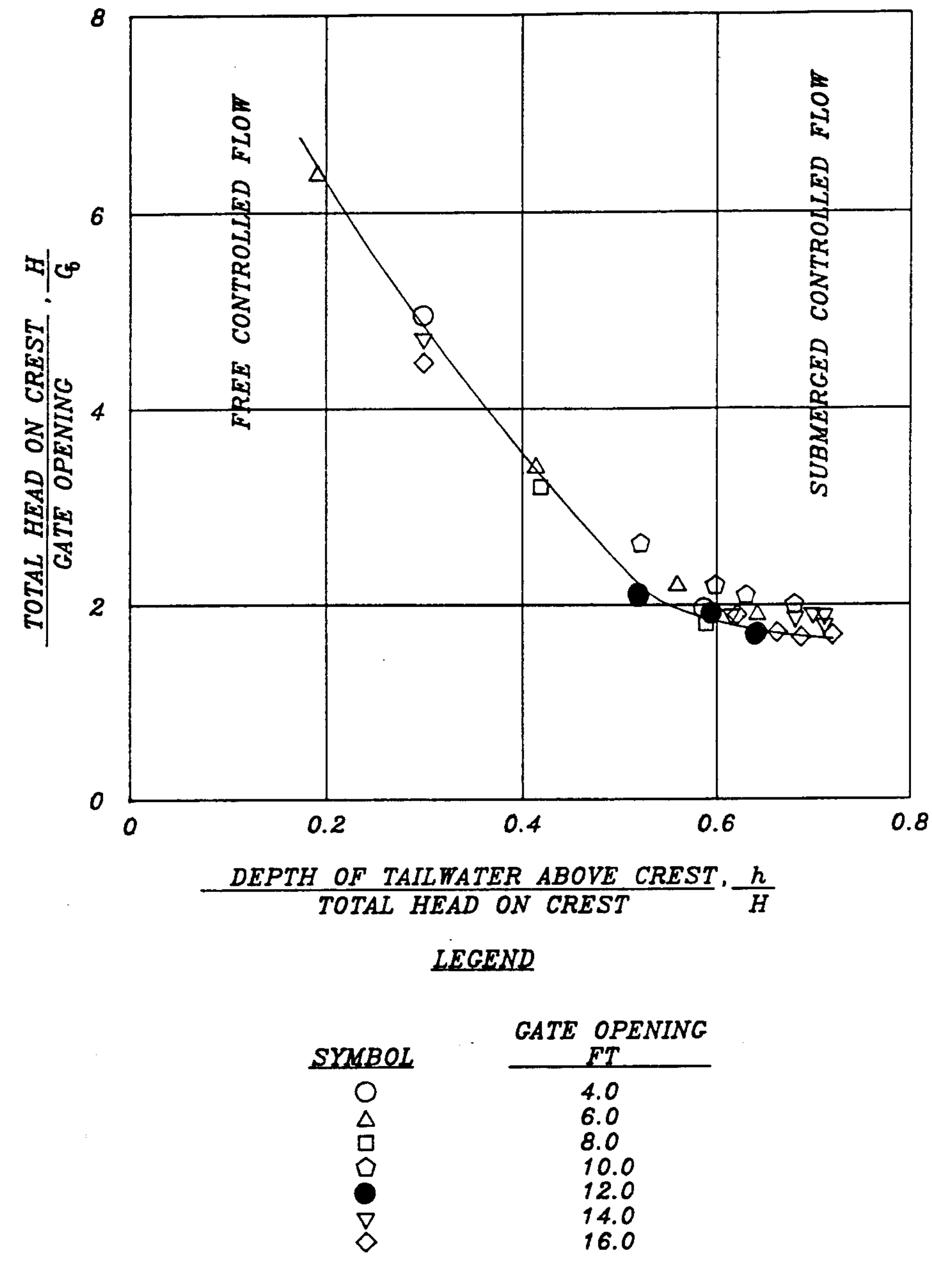
LEGEND

SYMBOL	*GATE OPENING FT*
○	4.0
△	6.0
□	8.0
⬡	10.0

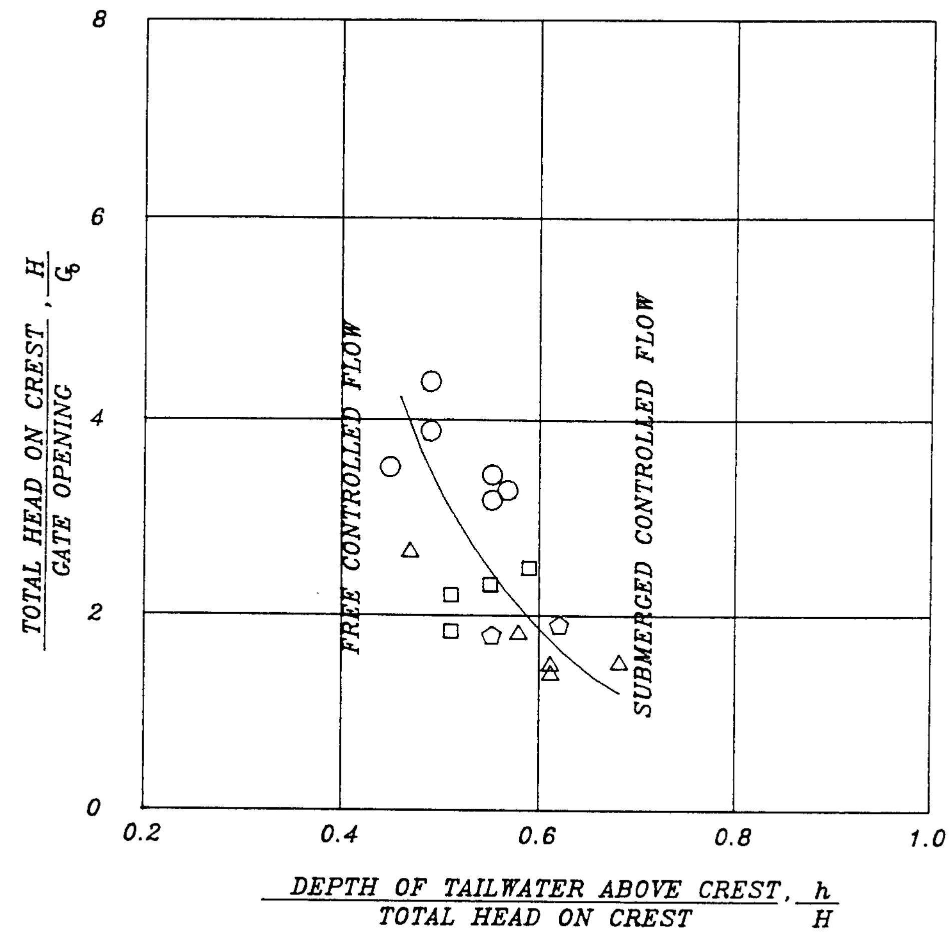
DISCHARGE COEFFICIENTS
FOR SUBMERGED CONTROLLED FLOW
CREST ELEVATION 704.7



DISCHARGE COEFFICIENT FOR
SUMERGED CONTROLLED FLOW
HIGH GATE BAY
CREST ELEVATION 714.0



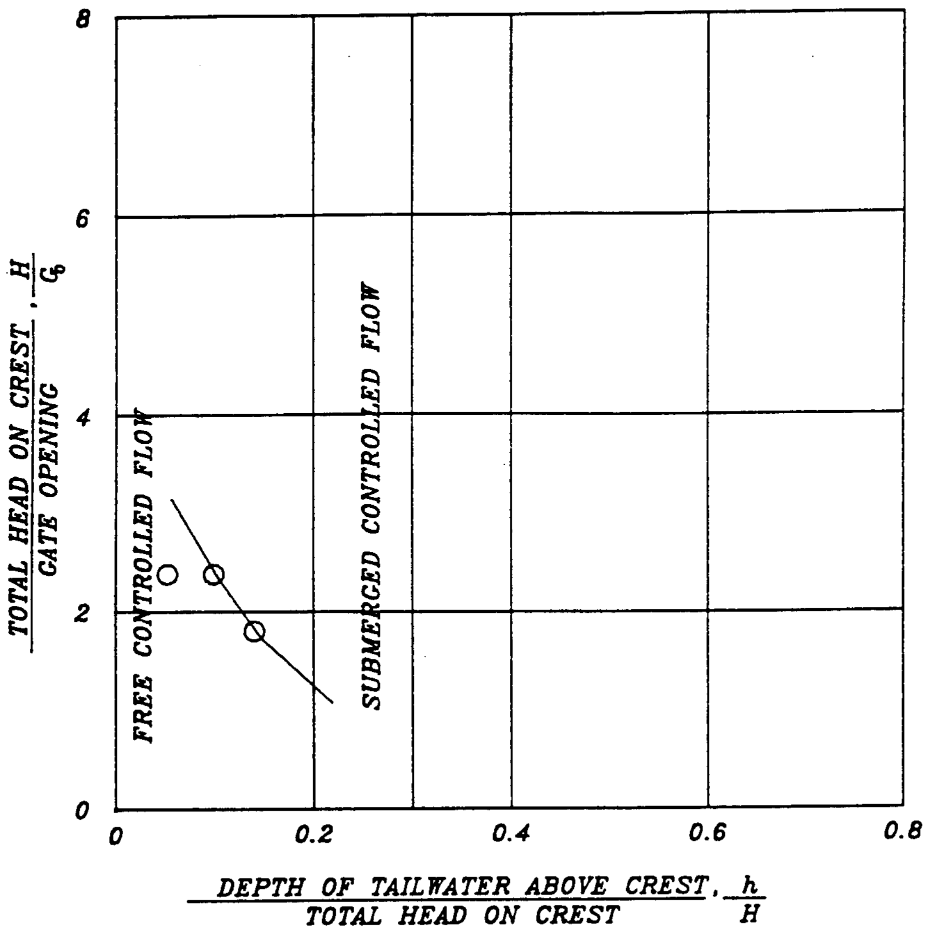
CONTROLLED FLOW REGIMES
CREST ELEVATION 696.7



LEGEND

SYMBOL	GATE OPENING FT
○	4.0
△	6.0
□	8.0
⬠	10.0

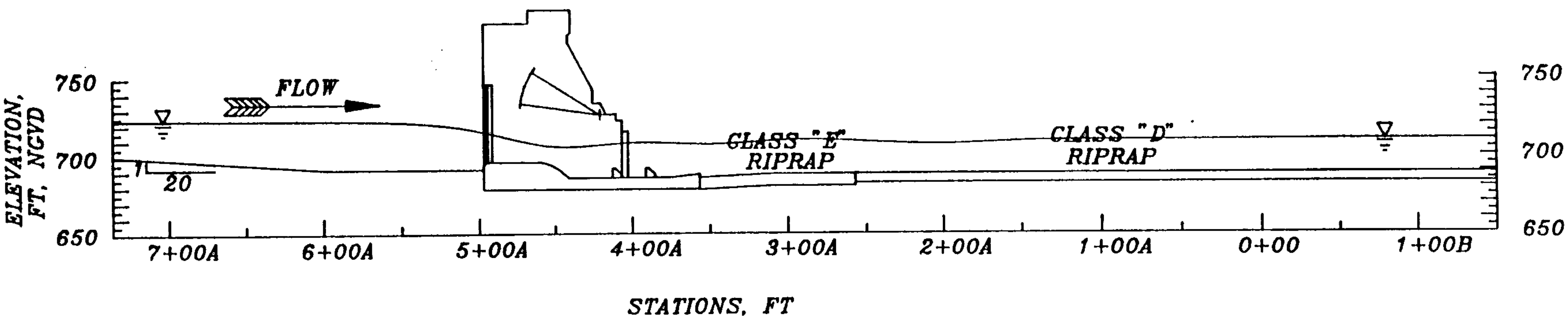
CONTROLLED FLOW REGIMES
CREST ELEVATION 704.7



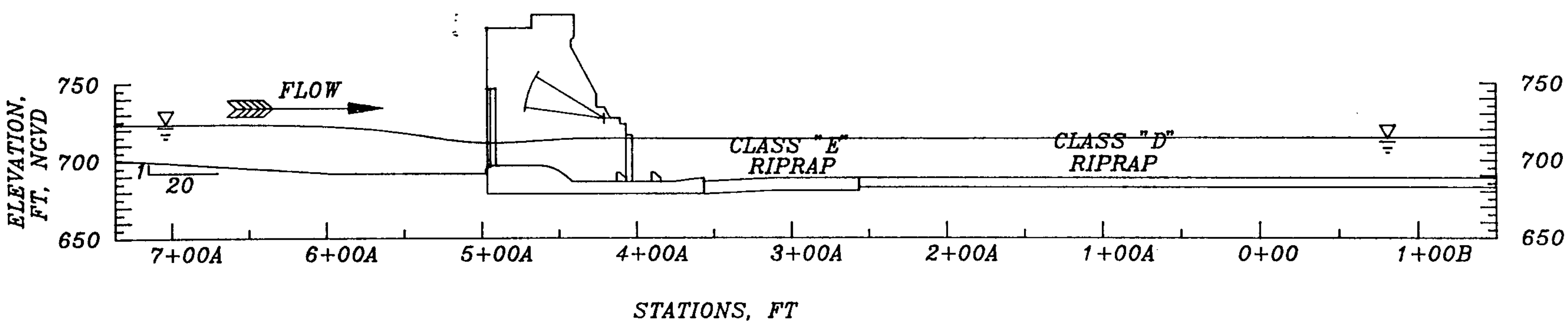
LEGEND

SYMBOL	GATE OPENING FT
O	4.0

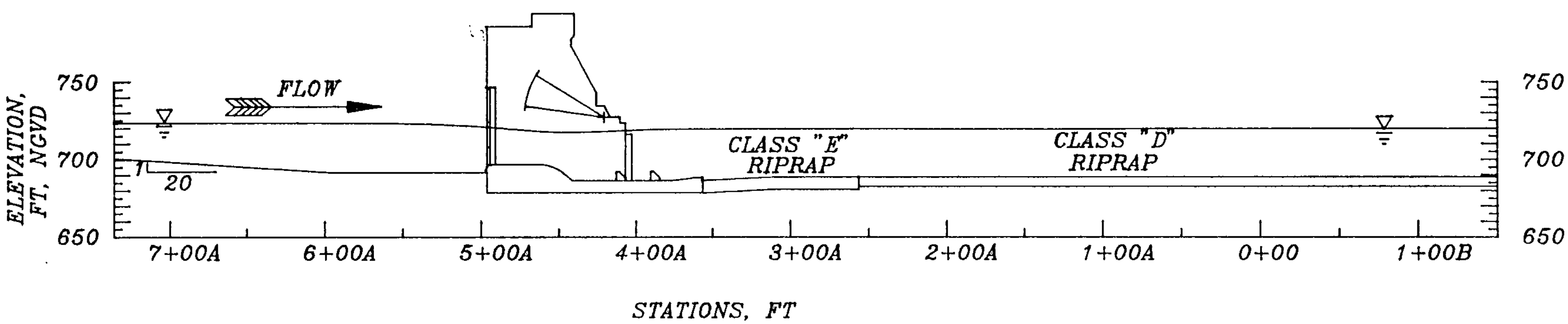
CONTROLLED FLOW REGIMES
CREST ELEVATION 714.0



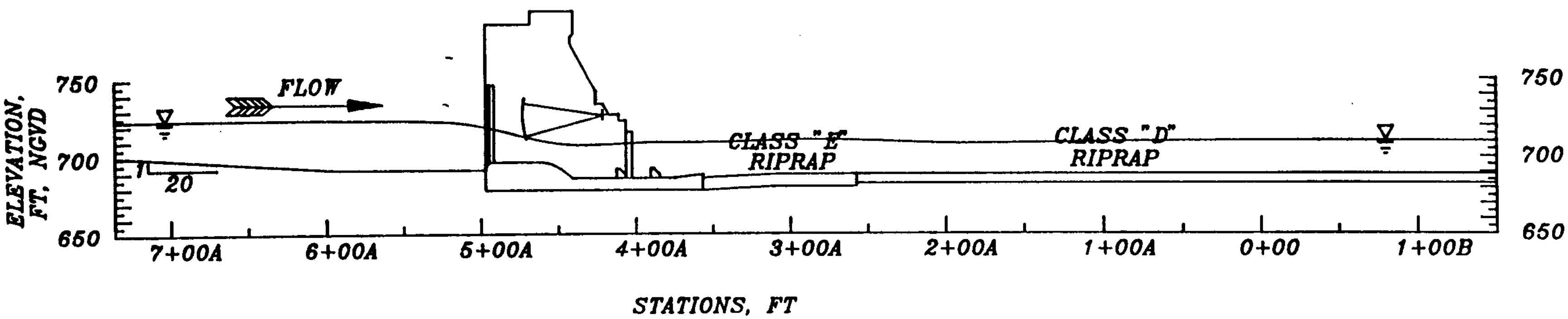
CENTER-LINE
WATER-SURFACE
PROFILE
TYPE 1 DESIGN
FULL GATE
Q = 45,900 CFS
TW EL 710.0



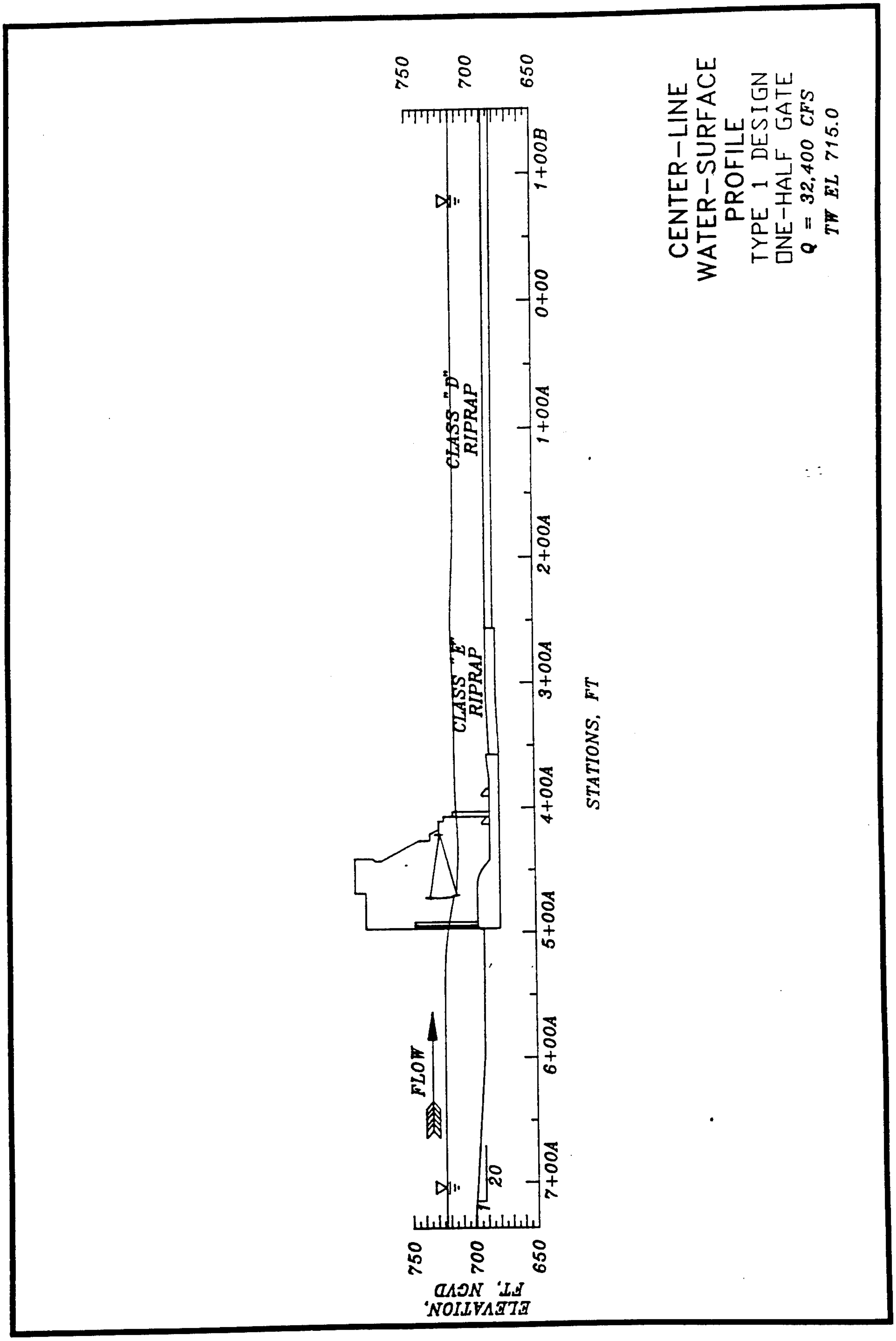
CENTER–LINE
WATER–SURFACE
PROFILE
TYPE 1 DESIGN
FULL GATE
Q = 45,900 CFS
TW EL 715.0

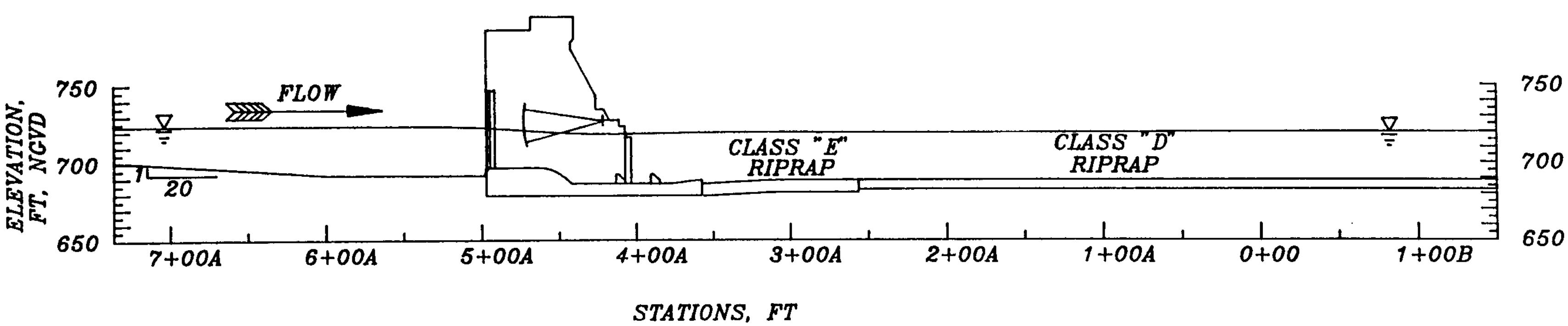


CENTER–LINE
WATER–SURFACE
PROFILE
TYPE 1 DESIGN
FULL GATE
Q = 42,000 CFS
TW EL 720.0

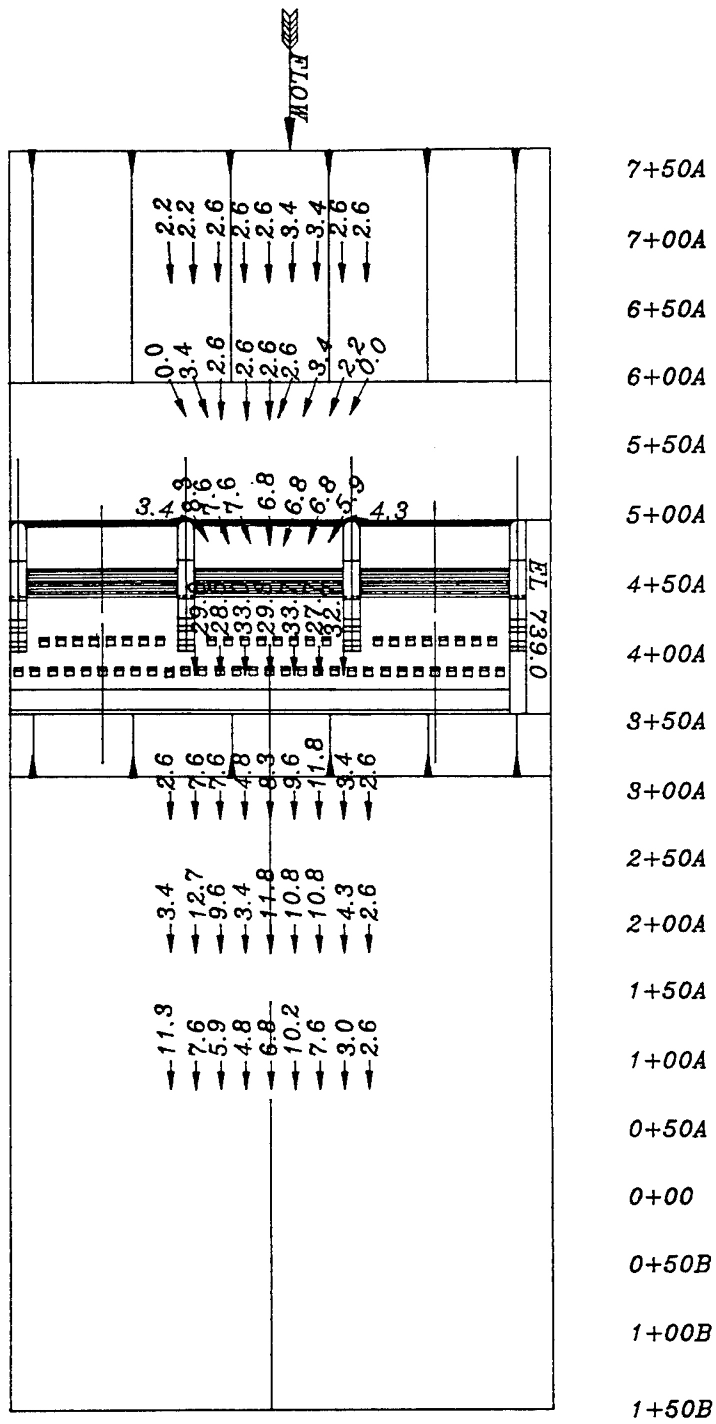


CENTER-LINE
WATER-SURFACE
PROFILE
TYPE 1 DESIGN
ONE-HALF GATE
Q = 34,600 CFS
TW EL 710.0


CENTER-LINE
WATER-SURFACE
PROFILE
TYPE 1 DESIGN
ONE-HALF GATE
Q = 32,400 CFS
TW EL 715.0
ELEVATION, FT, NGVD
750
700
650
STATIONS, FT
7+00A
6+00A
5+00A
4+00A
3+00A
2+00A
1+00A
0+00
1+00B
FLOW
CLASS "E" RIPRAP
CLASS "D" RIPRAP
20

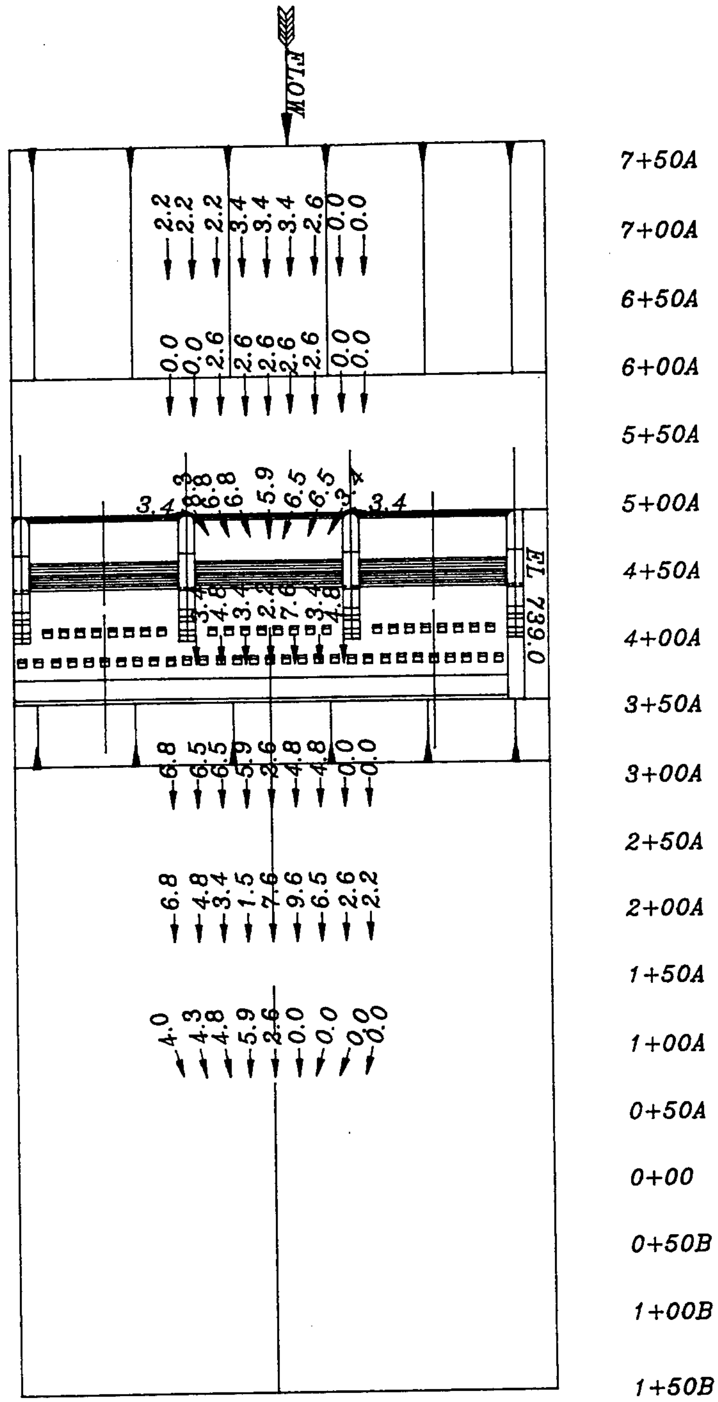


CENTER-LINE
WATER-SURFACE
PROFILE
TYPE 1 DESIGN
ONE-HALF GATE
Q = 18,300 CFS
TW EL 720.0



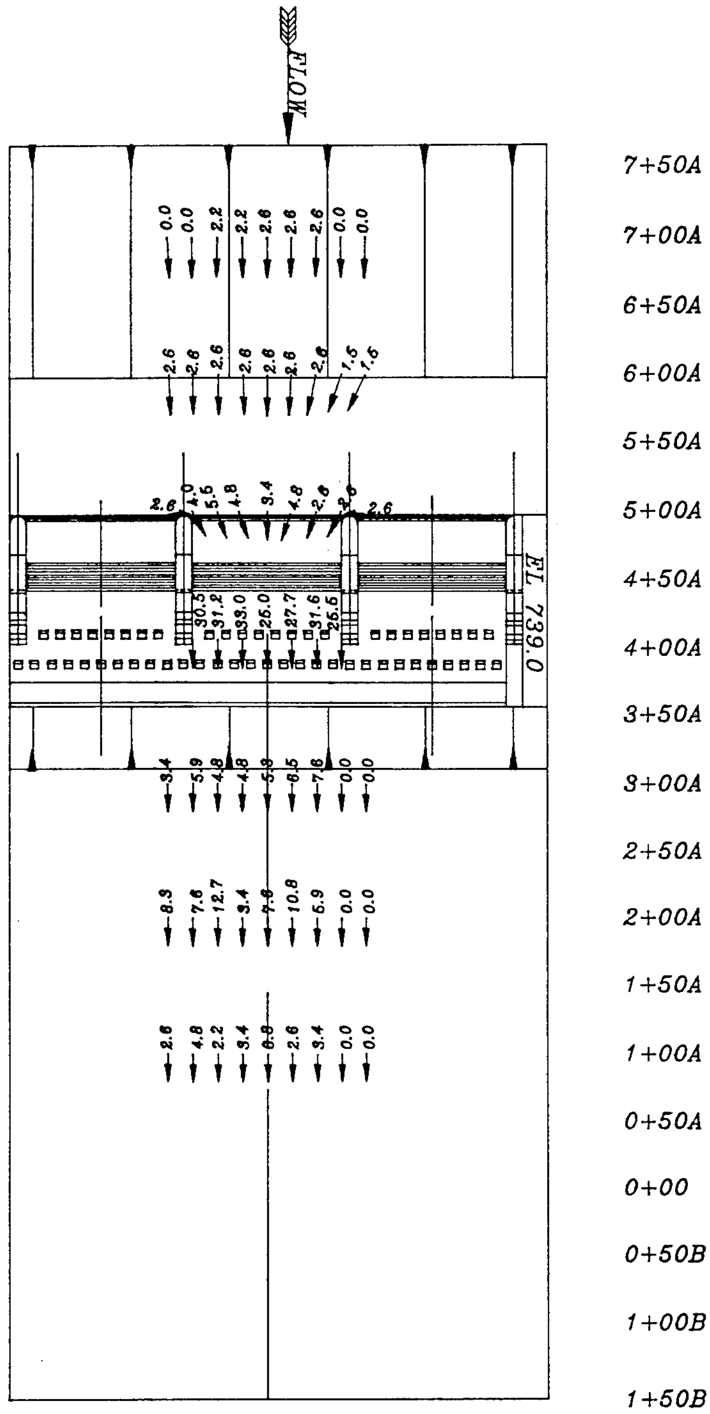
Note: *Crest El 696.7*
Velocities 1 ft above floor
Velocities measured in ft per sec

BOTTOM VELOCITIES
TYPE 1 DESIGN
FULL GATE
Q = 45,900 CFS
POOL EL 723.7, TW EL 710.0



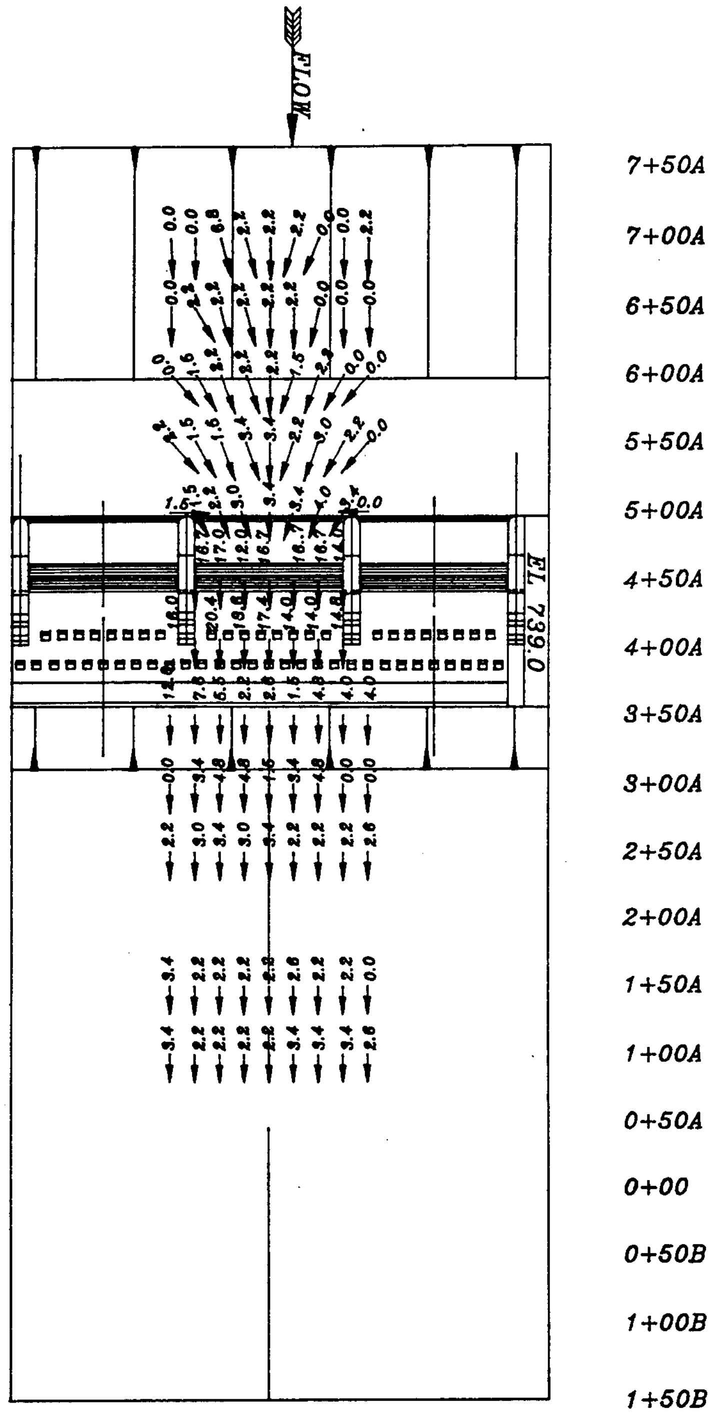
Note: *Crest El 696.7*
Velocities 1 ft above floor
Velocities measured in ft per sec

BOTTOM VELOCITIES
TYPE 1 DESIGN
FULL GATE
Q = 42,000 CFS
POOL EL 723.7, TW EL 720.0



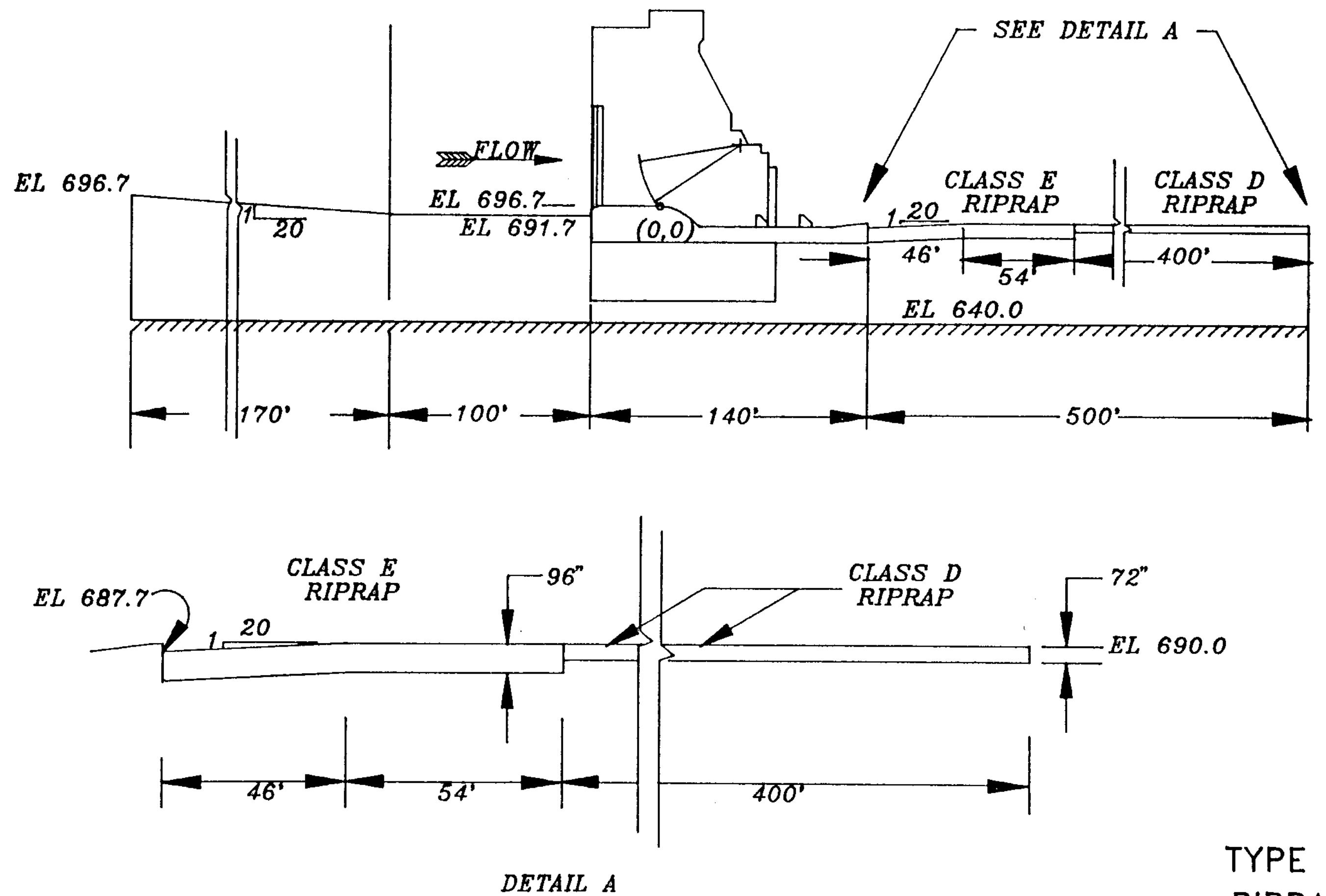
Note: *Crest El 696.7*
Velocities 1 ft above floor
Velocities measured in ft per sec

BOTTOM VELOCITIES
TYPE 1 DESIGN
HALF GATE
Q = 34,600 CFS
POOL EL 723.7, TW EL 710.0

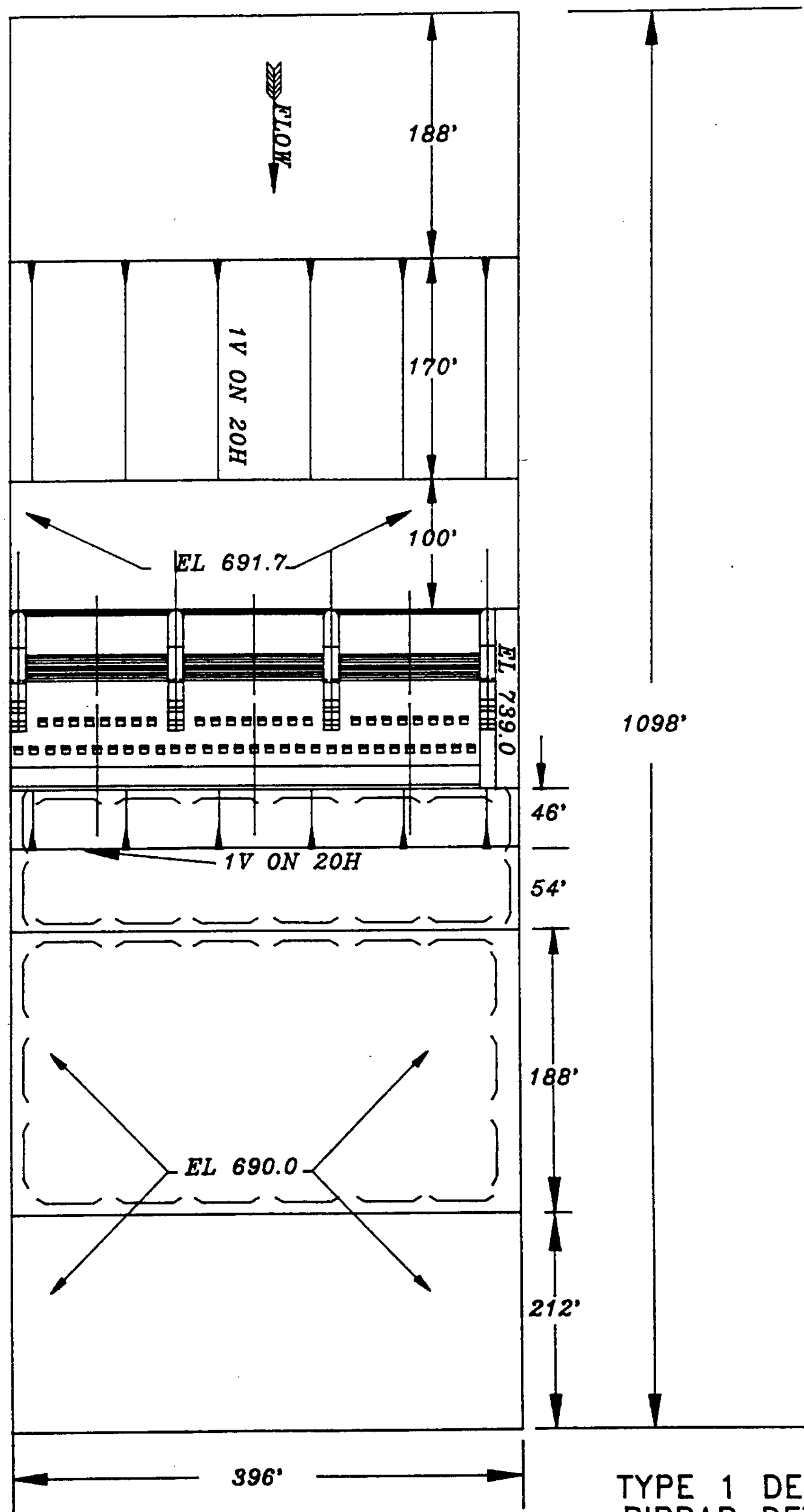


Note: *Crest El 696.7*
Velocities 1 ft above floor
Velocities measured in ft per sec

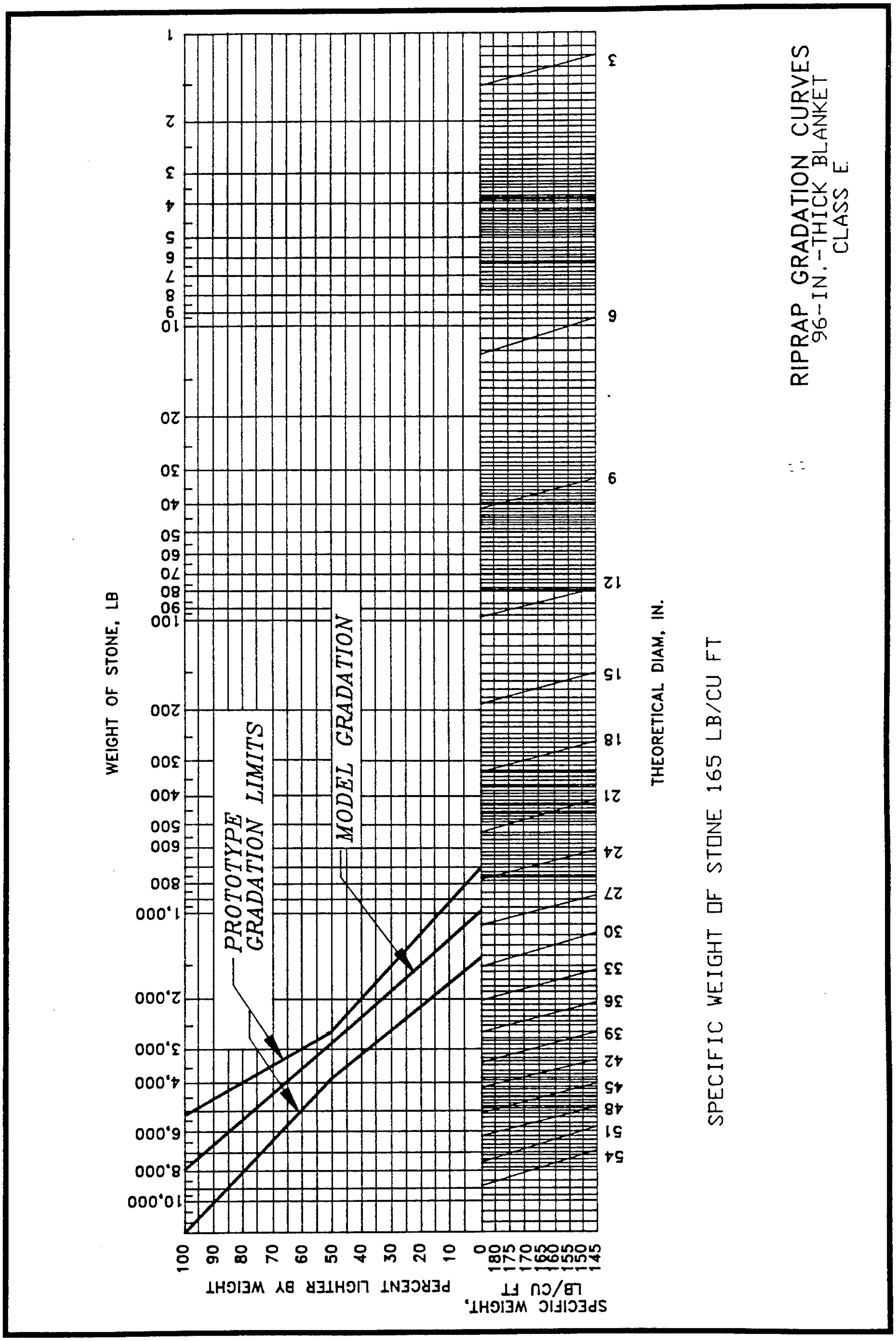
BOTTOM VELOCITIES
TYPE 1 DESIGN
HALF GATE
Q = 18,300 CFS
POOL EL 723.7, TW EL 720.0



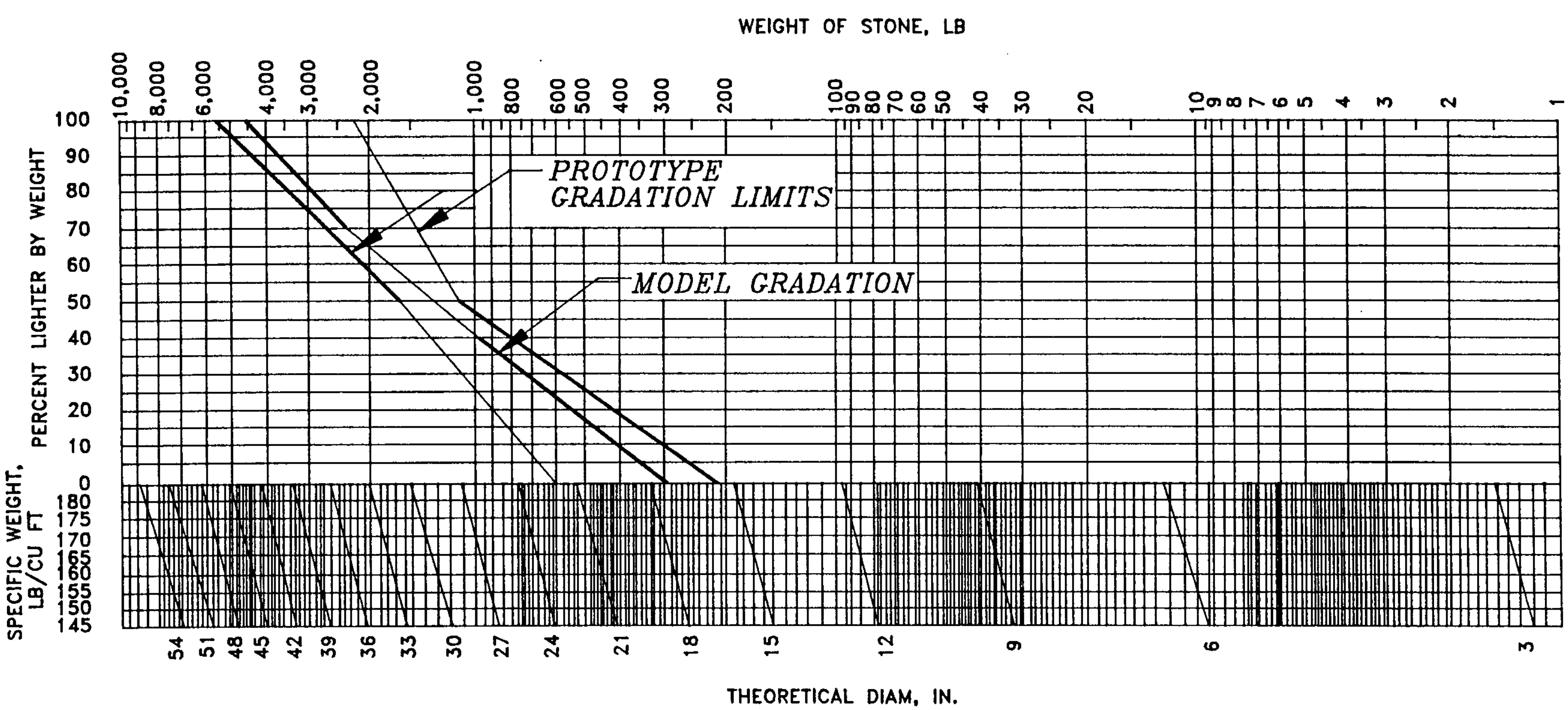
TYPE 1 DESIGN
RIPRAP DETAIL
PROFILE VIEW



TYPE 1 DESIGN
RIPRAP DETAIL
PLAN VIEW

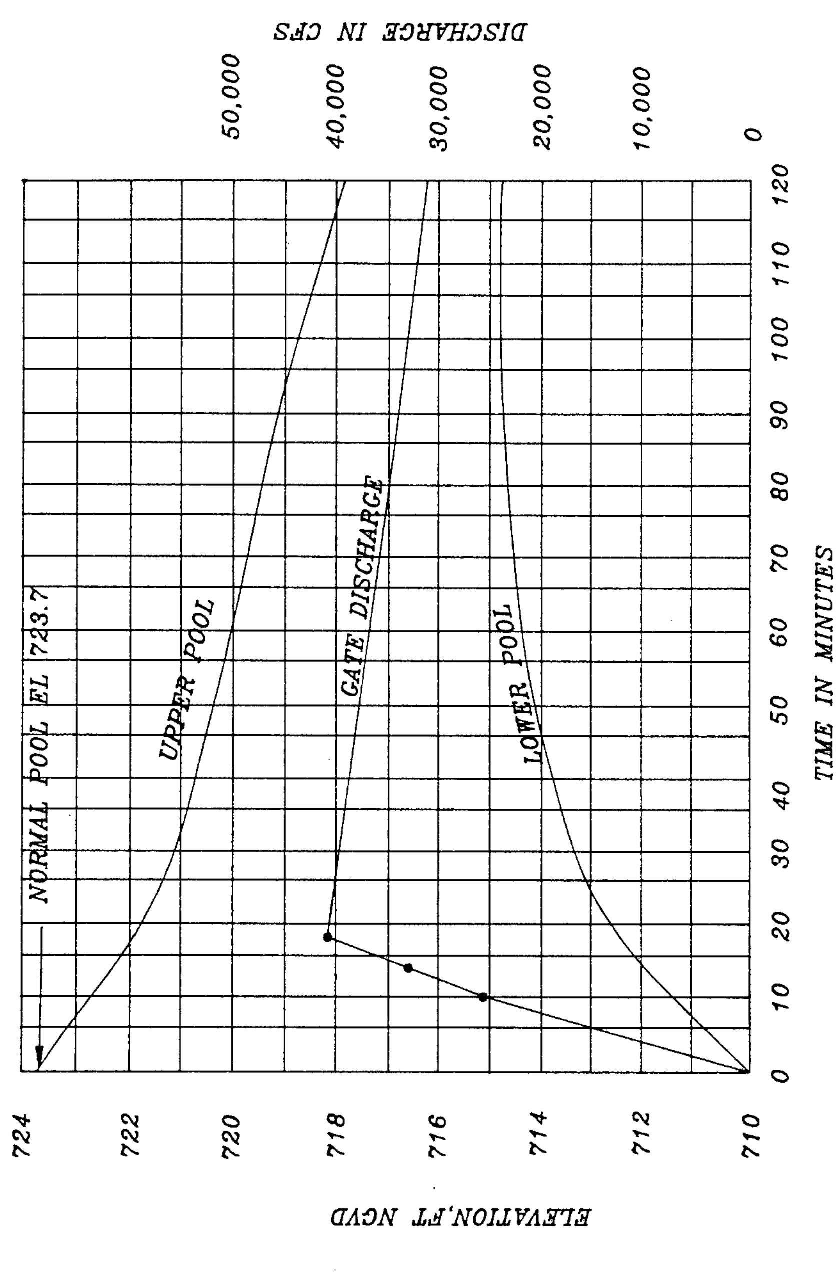


RIPRAP GRADATION CURVES
96-IN.-THICK BLANKET
CLASS E
SPECIFIC WEIGHT OF STONE 165 LB/CU FT
WEIGHT OF STONE, LB
THEORETICAL DIAM, IN.
PERCENT LIGHTER BY WEIGHT
SPECIFIC WEIGHT, LB/CU FT
PROTOTYPE GRADATION LIMITS
MODEL GRADATION
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
800
1,000
2,000
3,000
4,000
6,000
8,000
10,000
3
6
9
12
15
18
21
24
27
30
33
36
39
42
45
48
51
54
100
90
80
70
60
50
40
30
20
10
0
180
175
170
165
160
155
150
145

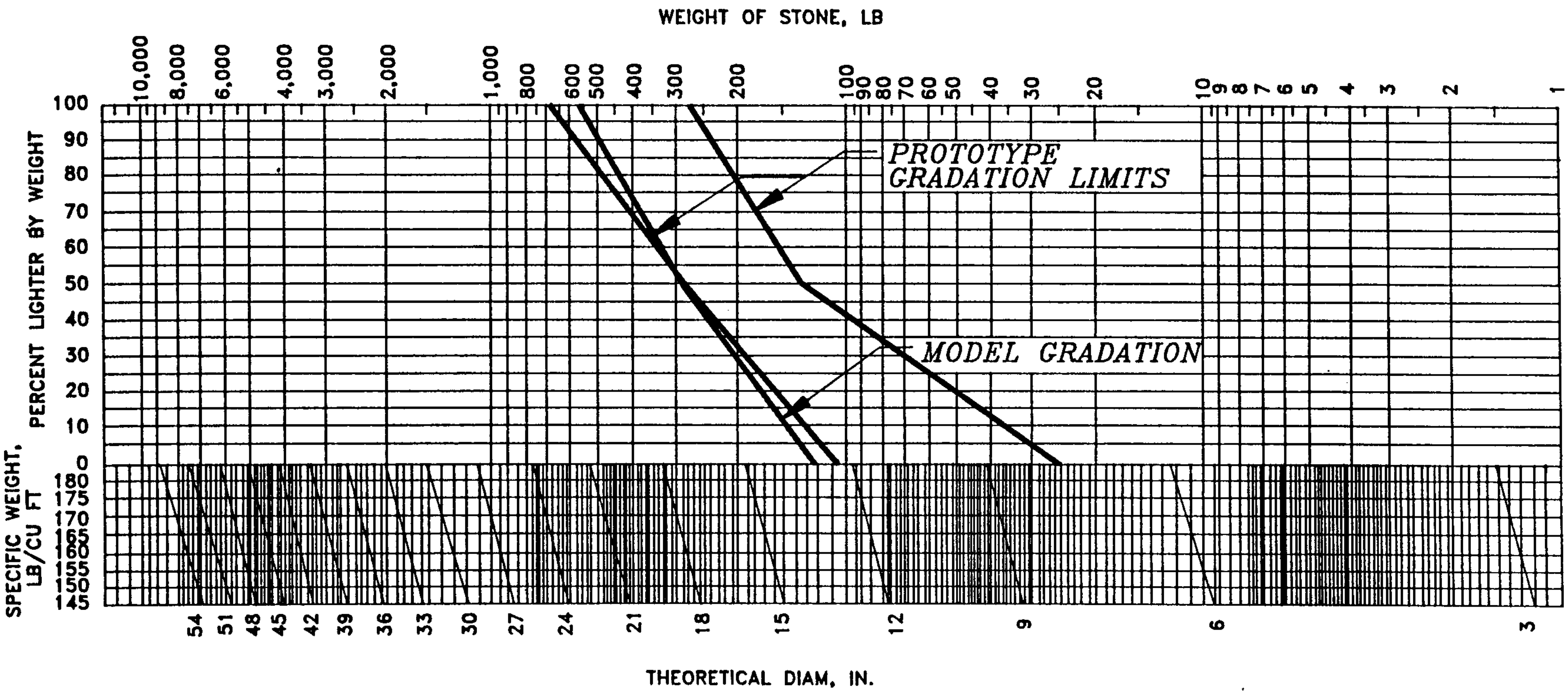


SPECIFIC WEIGHT OF STONE 165 LB/CU FT

RIPRAP GRADATION CURVES
72-IN.-THICK BLANKET
CLASS D

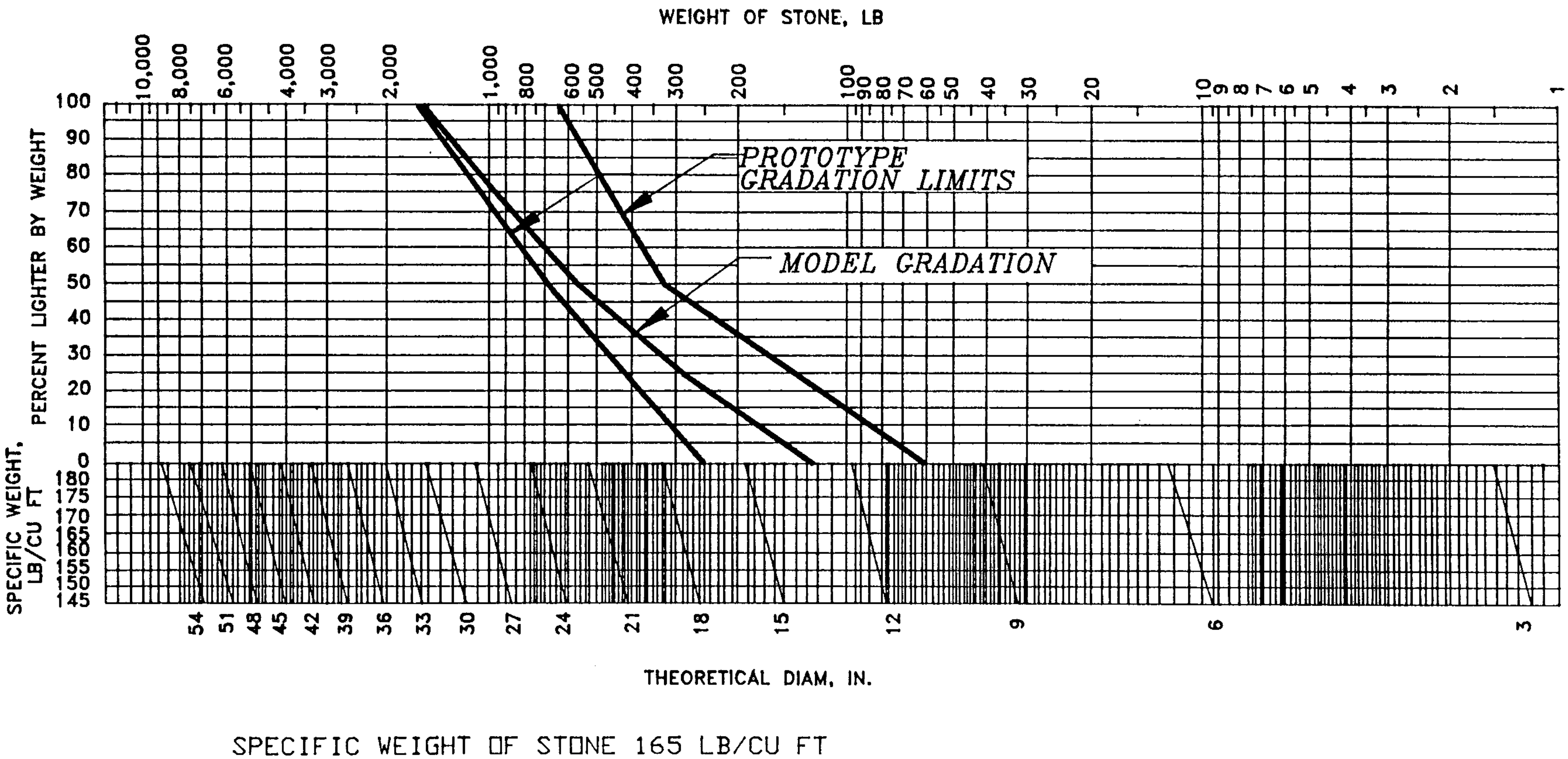


COMPUTED HYDROGRAPHS
SINGLE GATE OPENED FULL
1 FT/MIN DURING LOW FLOW

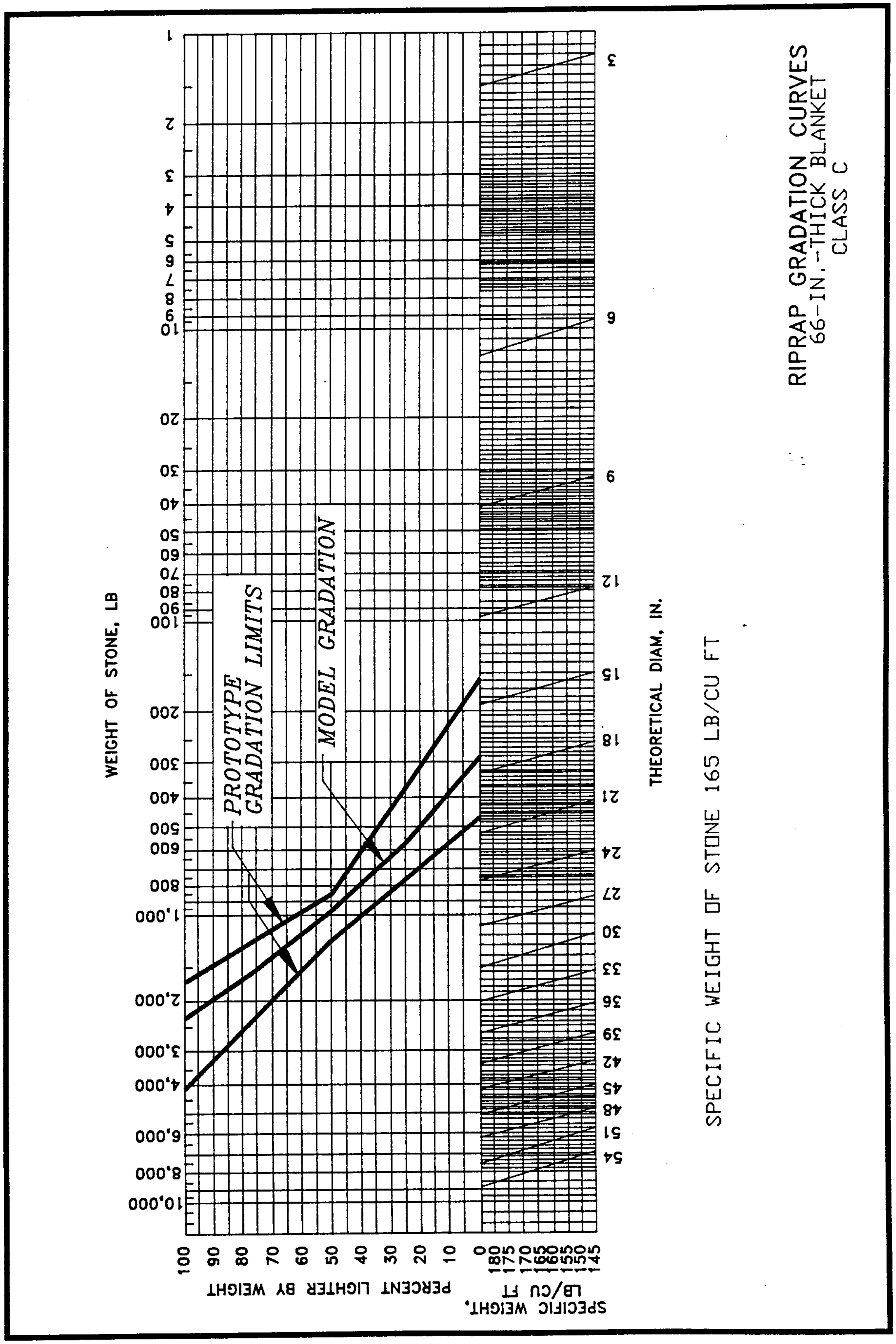


SPECIFIC WEIGHT OF STONE 165 LB/CU FT

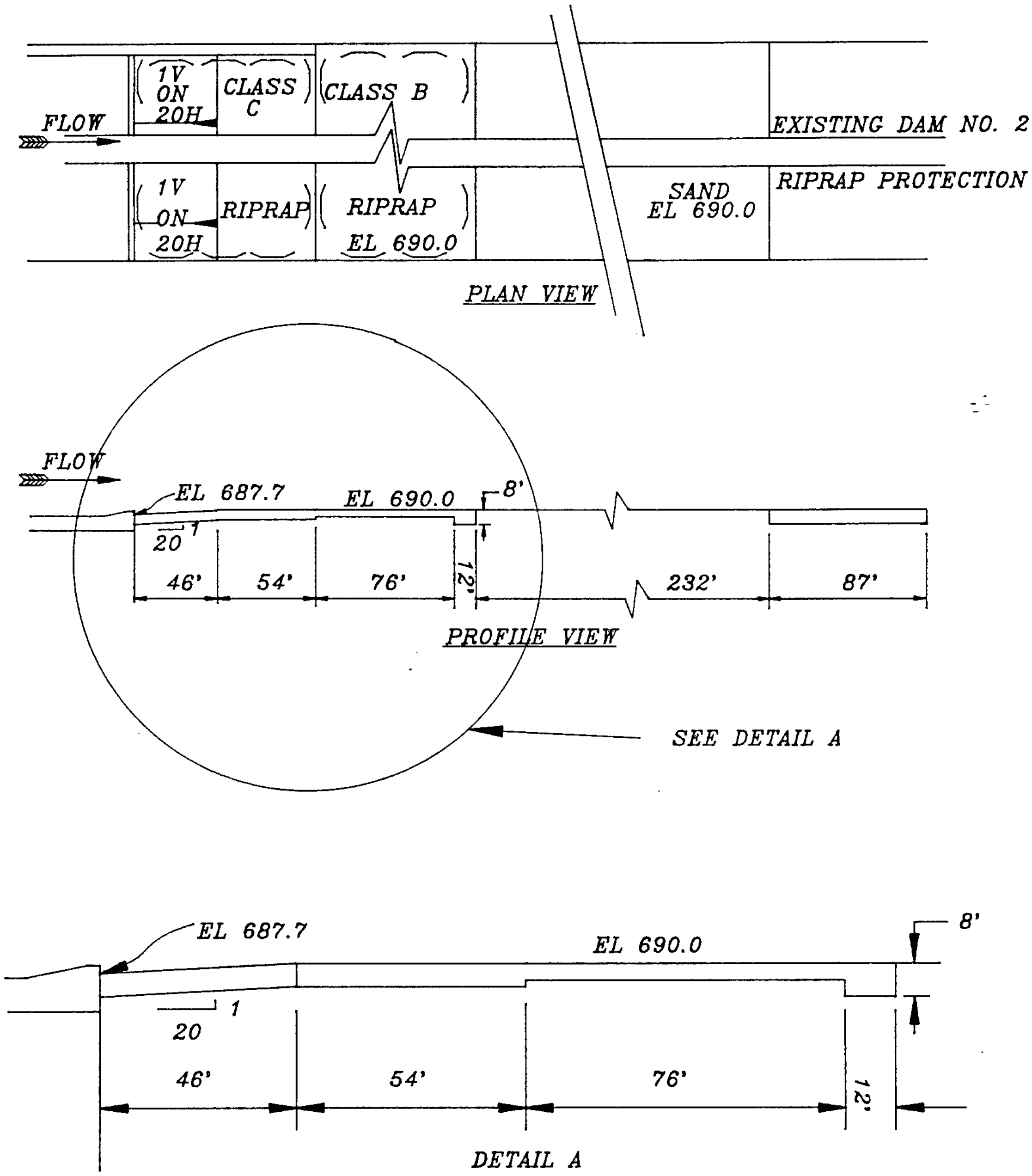
RIPRAP GRADATION CURVES
36-IN-THICK BLANKET
CLASS A



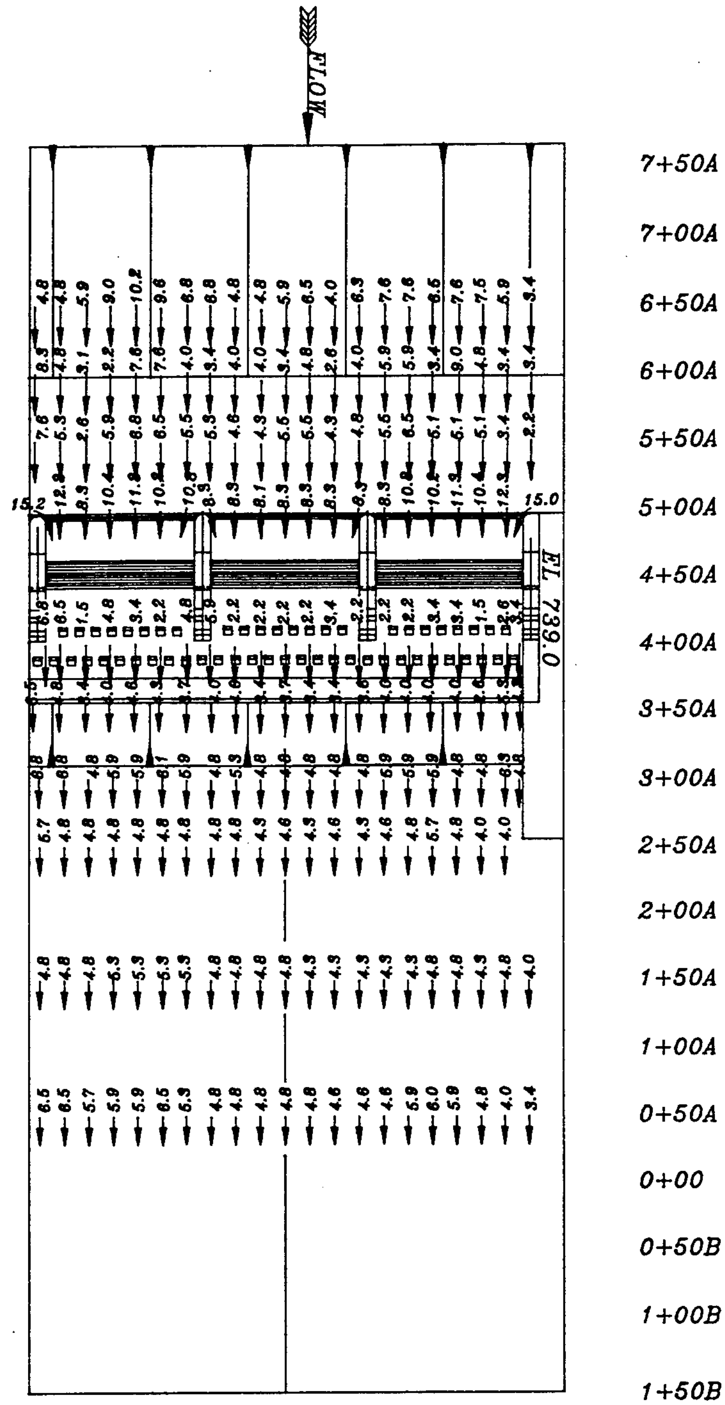
RIPRAP GRADATION CURVES
48-IN.-THICK BLANKET
CLASS B



RIPRAP GRADATION CURVES
66-IN.-THICK BLANKET
CLASS C

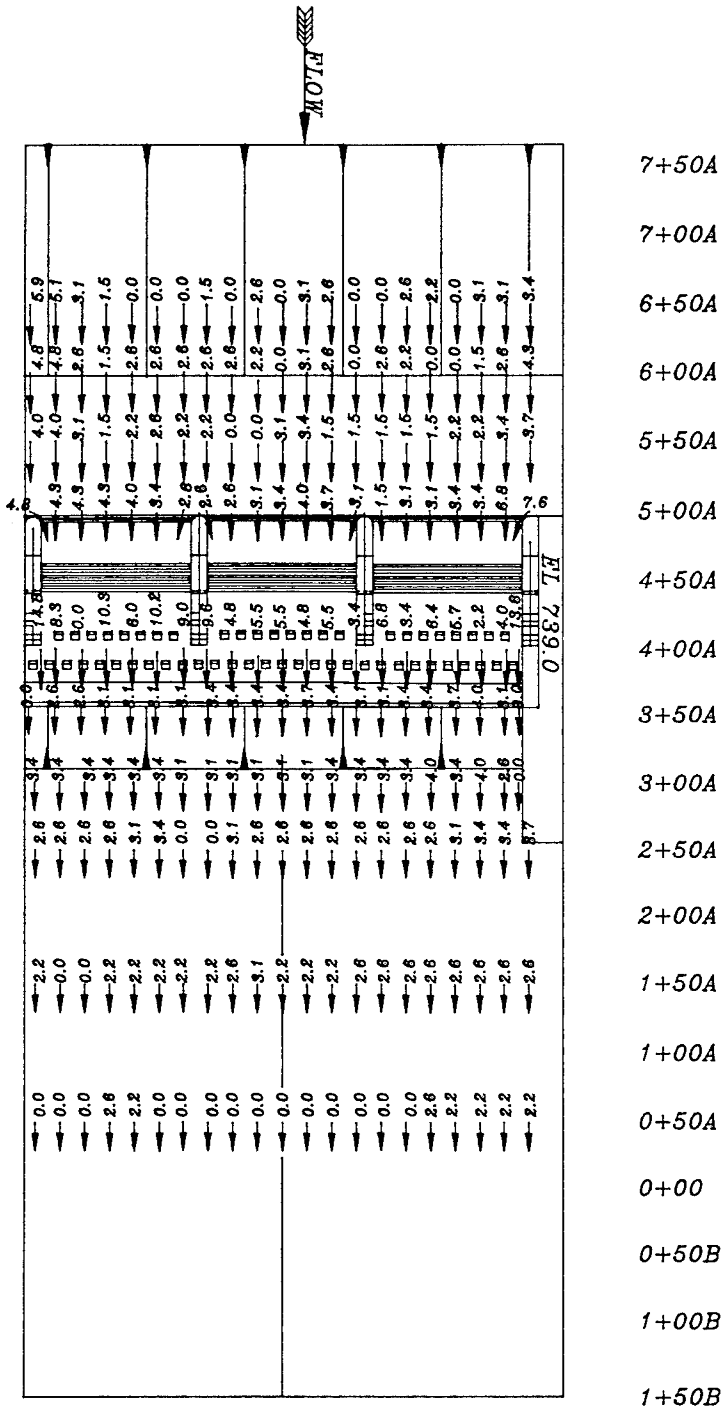


OPTION A
RIPRAP DETAIL



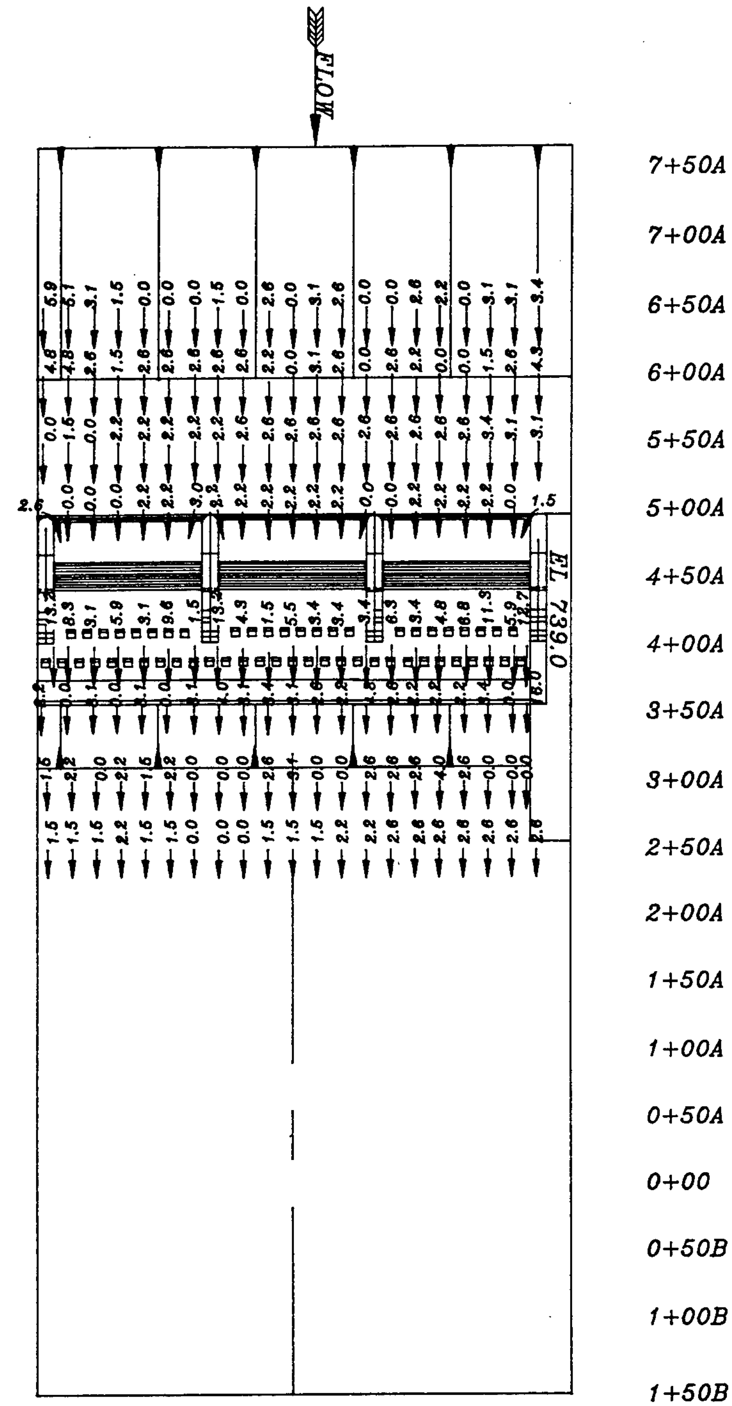
Note: Crest El 696.7
Velocities 1 ft above basin floor
Velocities 2 ft above riprap
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION A RIPRAP
ALL THREE GATES OPEN FULL
Q = 90,000 CFS
POOL EL 723.7, TW EL 722.5



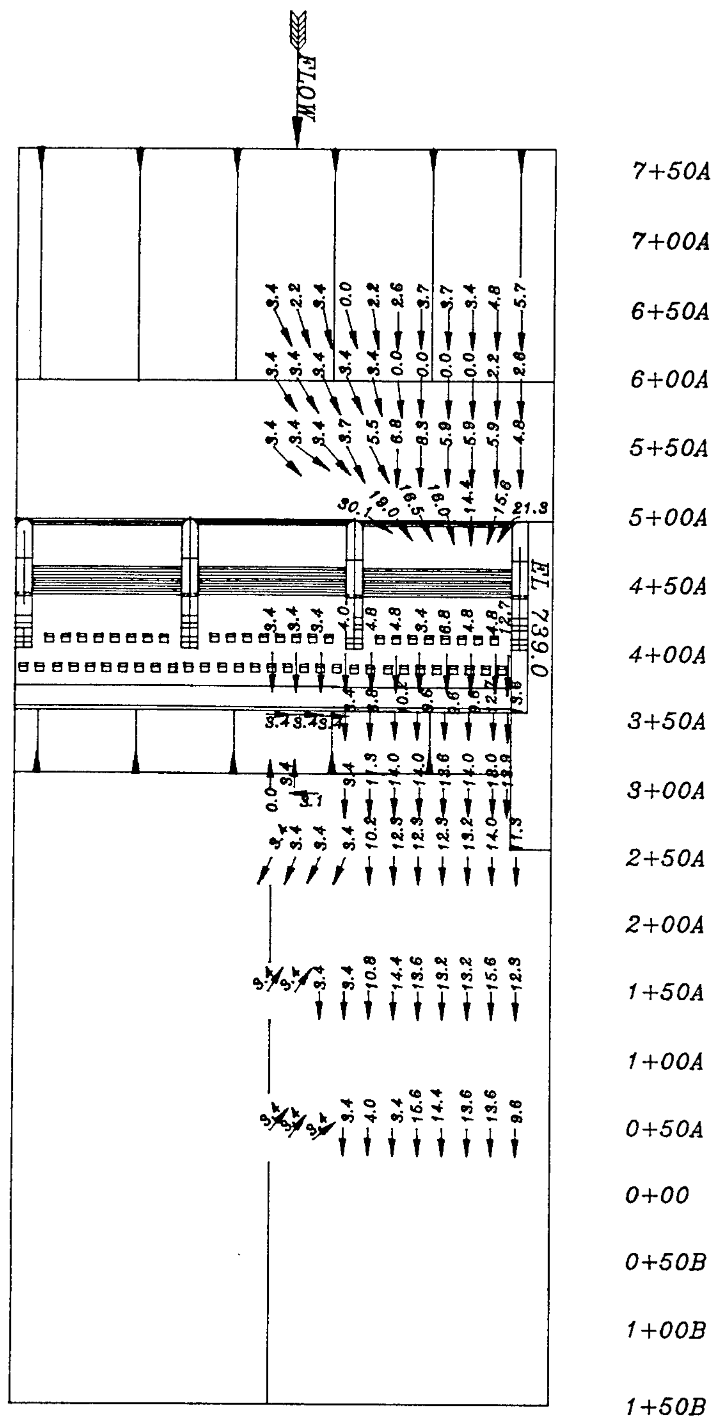
Note: *Crest El 696.7*
Velocities 1 ft above basin floor
Velocities 2 ft above riprap
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION A RIPRAP
ALL THREE GATES OPEN 10 FT
Q = 45,000 CFS
POOL EL 723.7, TW EL 719.0



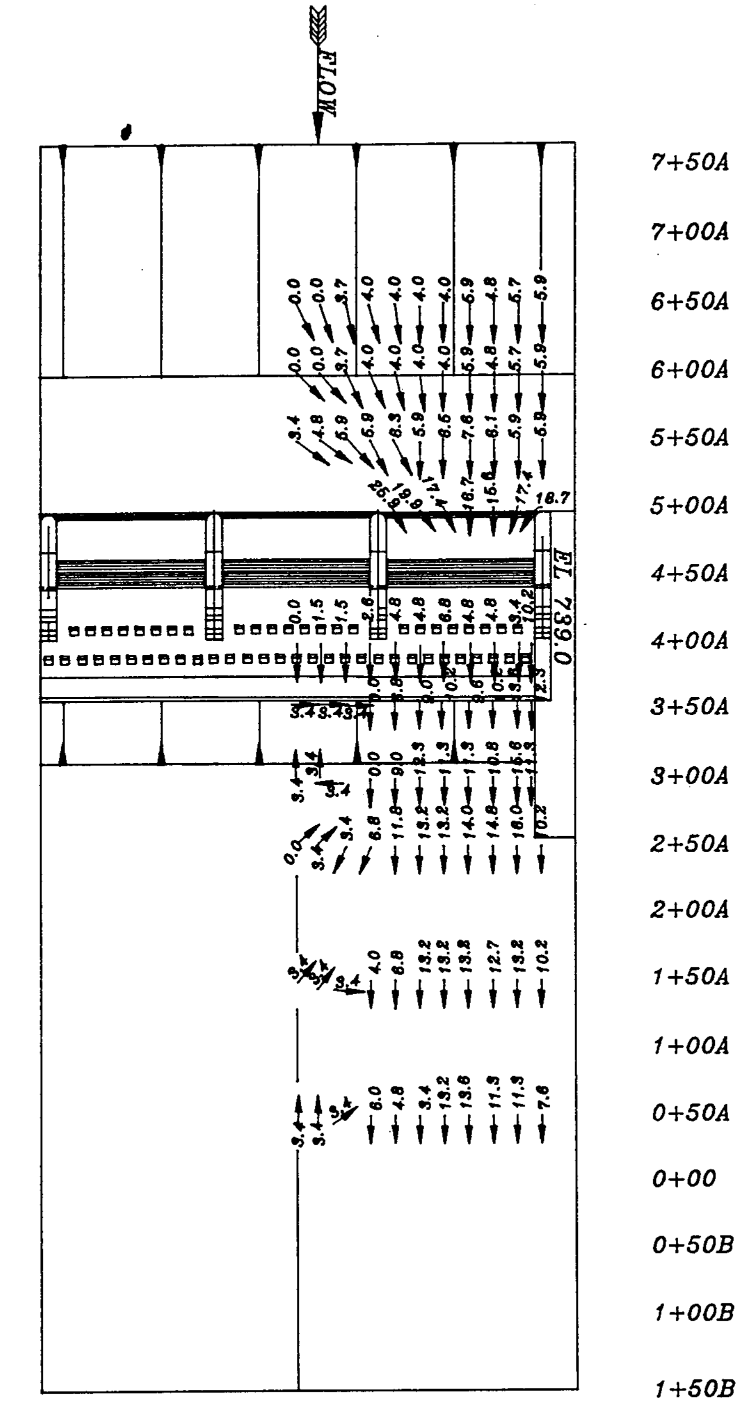
Note: *Crest El 696.7*
Velocities 1 ft above basin floor
Velocities 2 ft above riprap
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION A RIPRAP
ALL THREE GATES OPEN 4 FT
Q = 25,000 CFS
POOL EL 723.7, TW EL 715.0



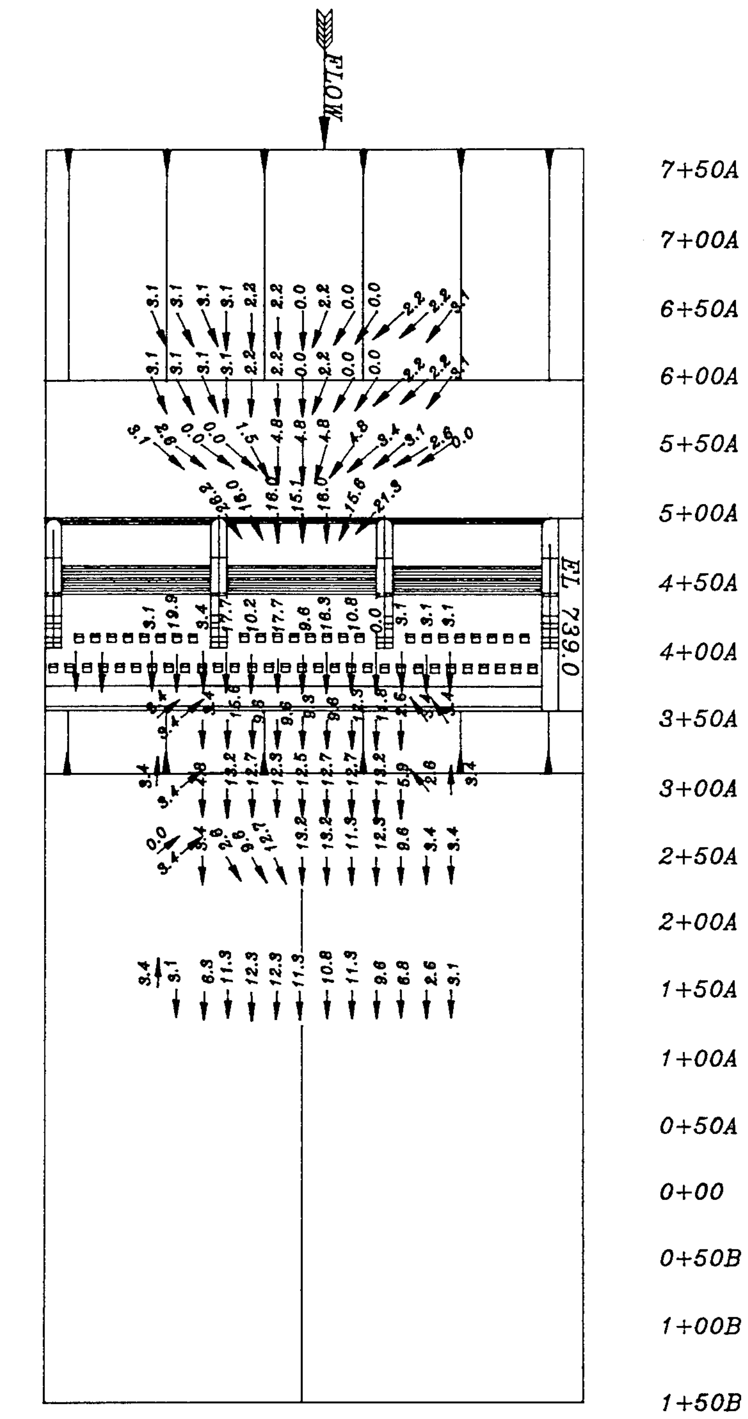
Note: *Crest El 696.7*
Velocities 1 ft above basin floor
Velocities 2 ft above riprap
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION A RIPRAP
LEFT GATE OPEN FULL
Q = 44,000 CFS
POOL EL 721.8, TW EL 712.5



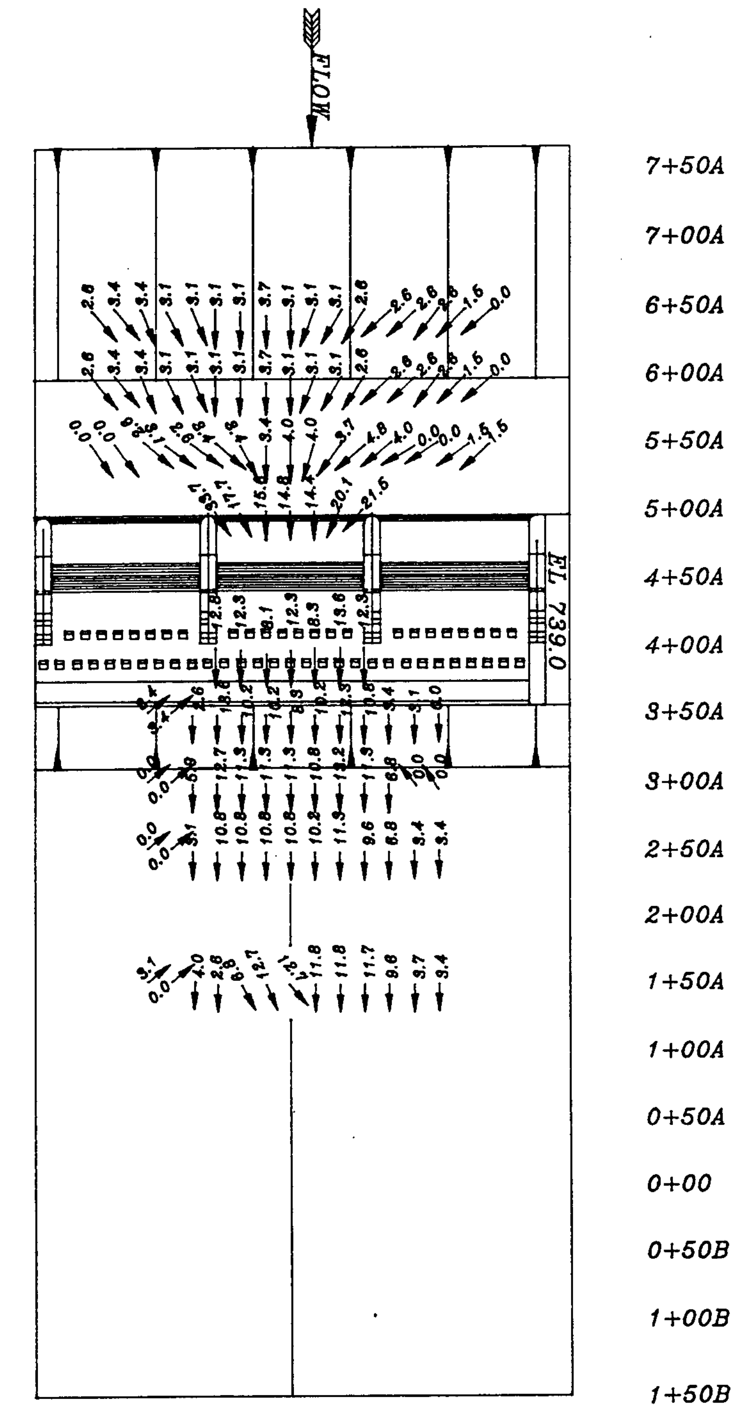
Note: *Crest El 696.7*
Velocities 1 ft above basin floor
Velocities 2 ft above riprap
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION A RIPRAP
LEFT GATE OPEN FULL
Q = 45,000 CFS
POOL EL 723.7, TW EL 715.2



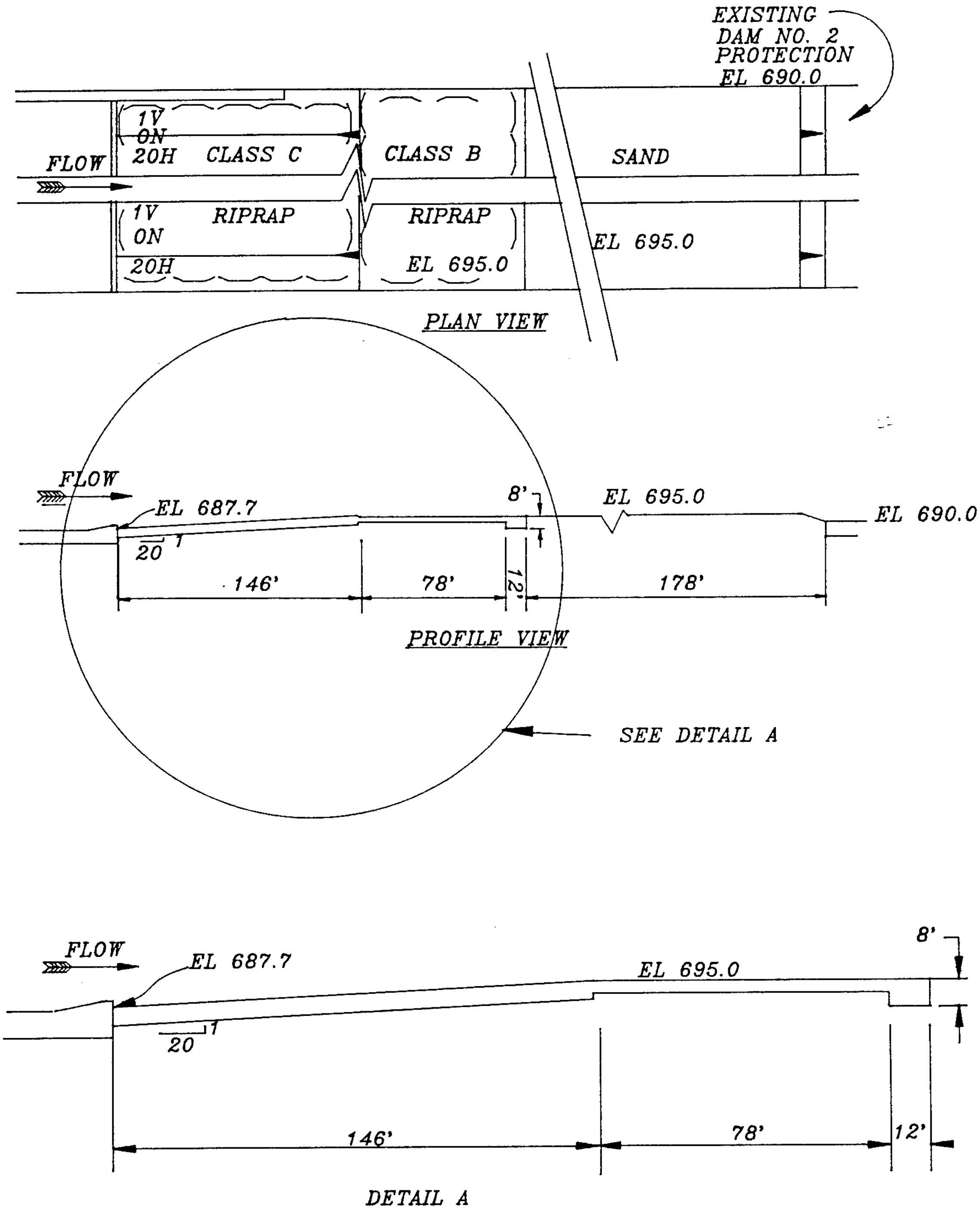
Note: *Crest El 696.7*
Velocities 1 ft above basin floor
Velocities 2 ft above riprap
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION A RIPRAP
MIDDLE GATE OPEN FULL
Q = 44,000 CFS
POOL EL 721.8, TW EL 712.5

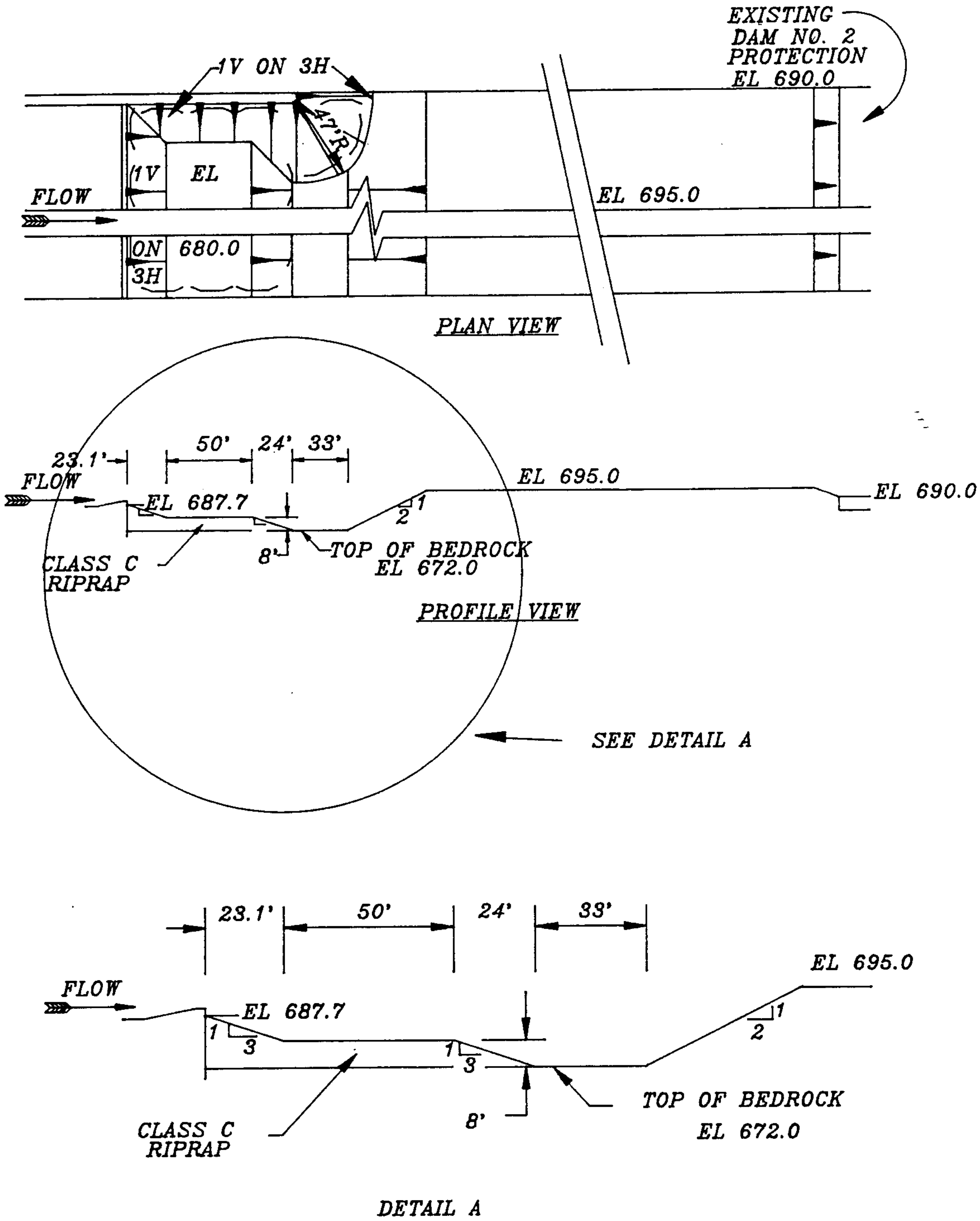


Note: *Crest El 696.7*
Velocities 1 ft above basin floor
Velocities 2 ft above riprap
Velocities measured in ft per sec

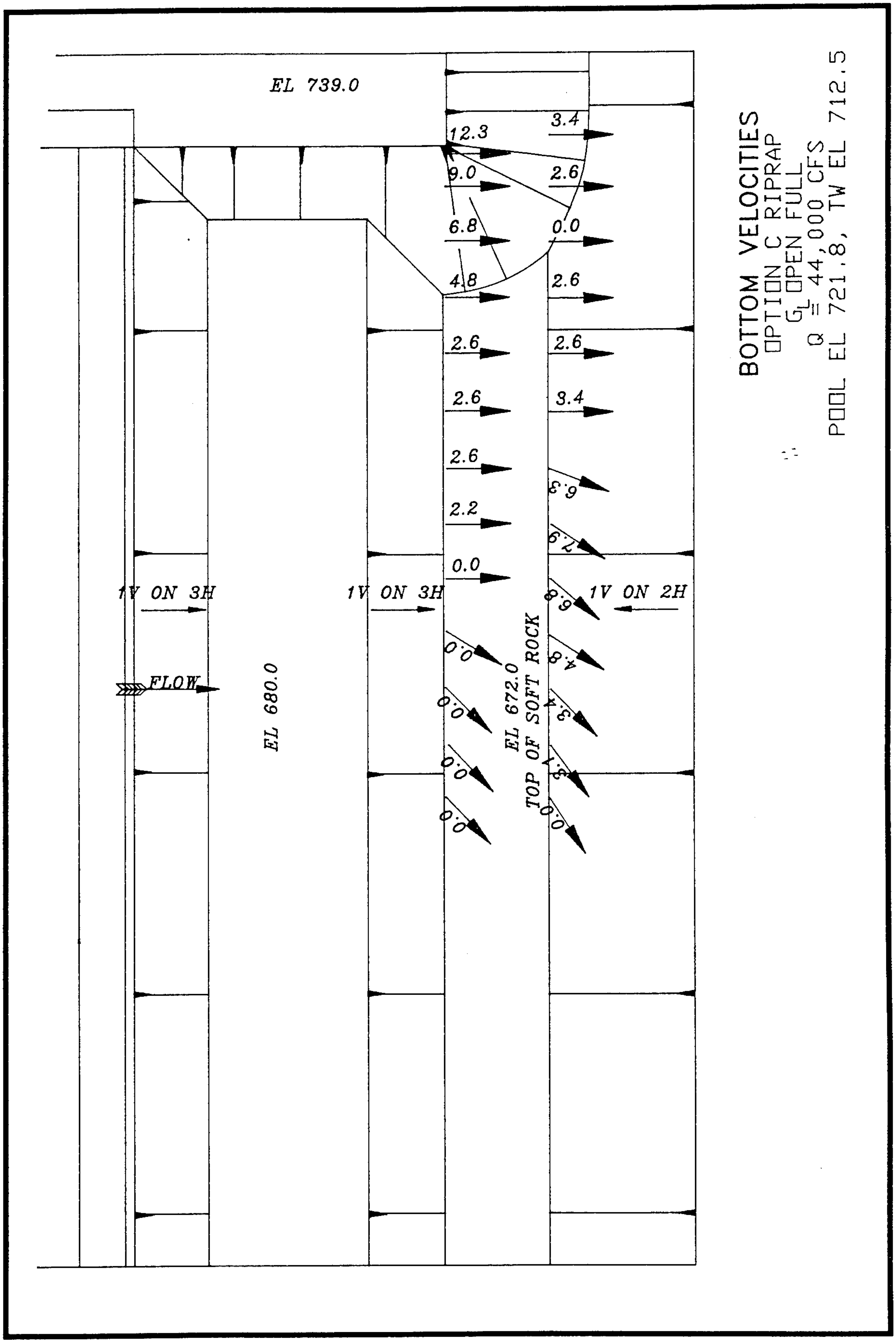
BOTTOM VELOCITIES
OPTION A RIPRAP
MIDDLE GATE OPEN FULL
Q = 45,000 CFS
POOL EL 723.7, TW EL 715.2

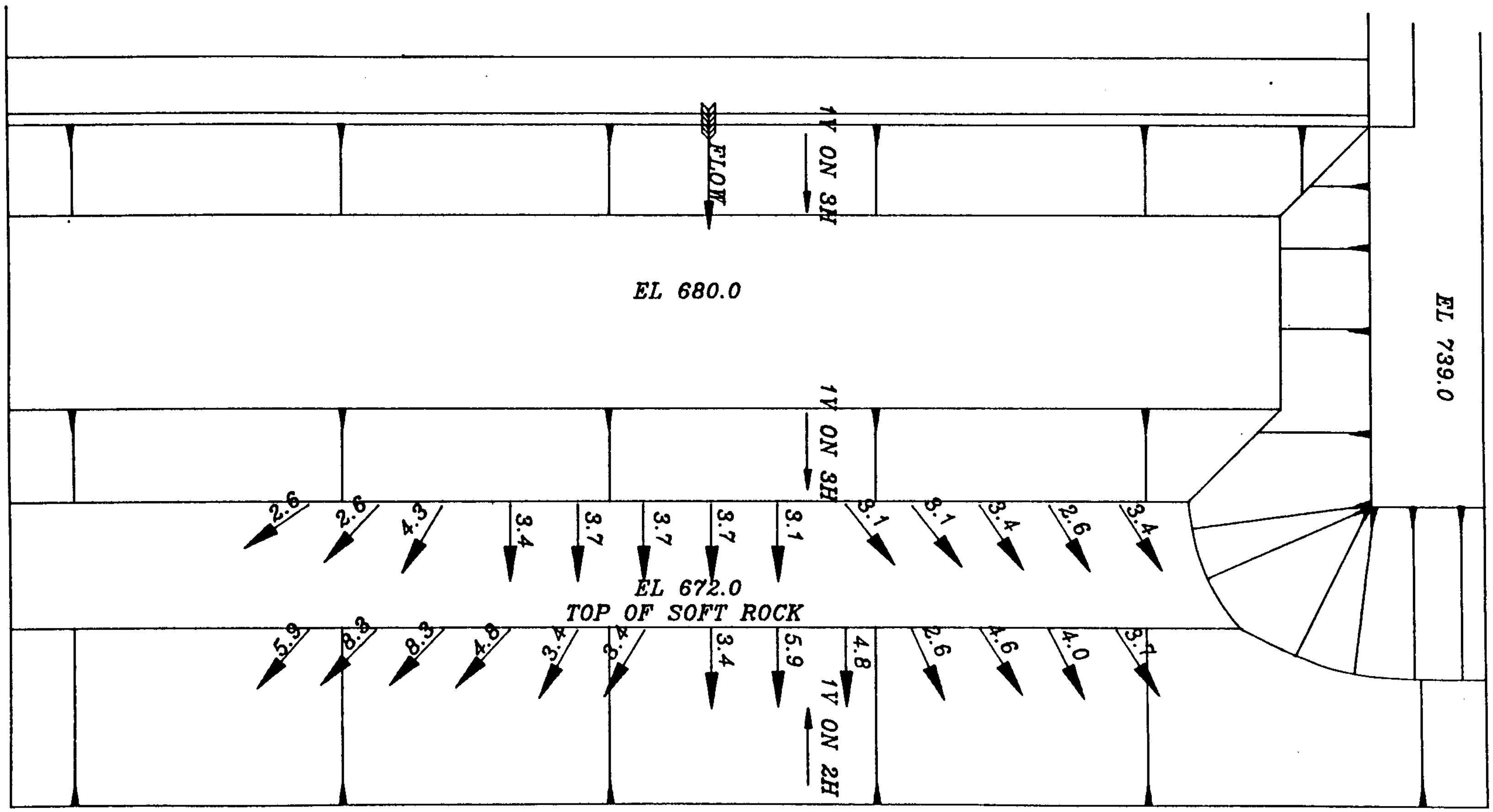


OPTION B
RIPRAP DETAIL



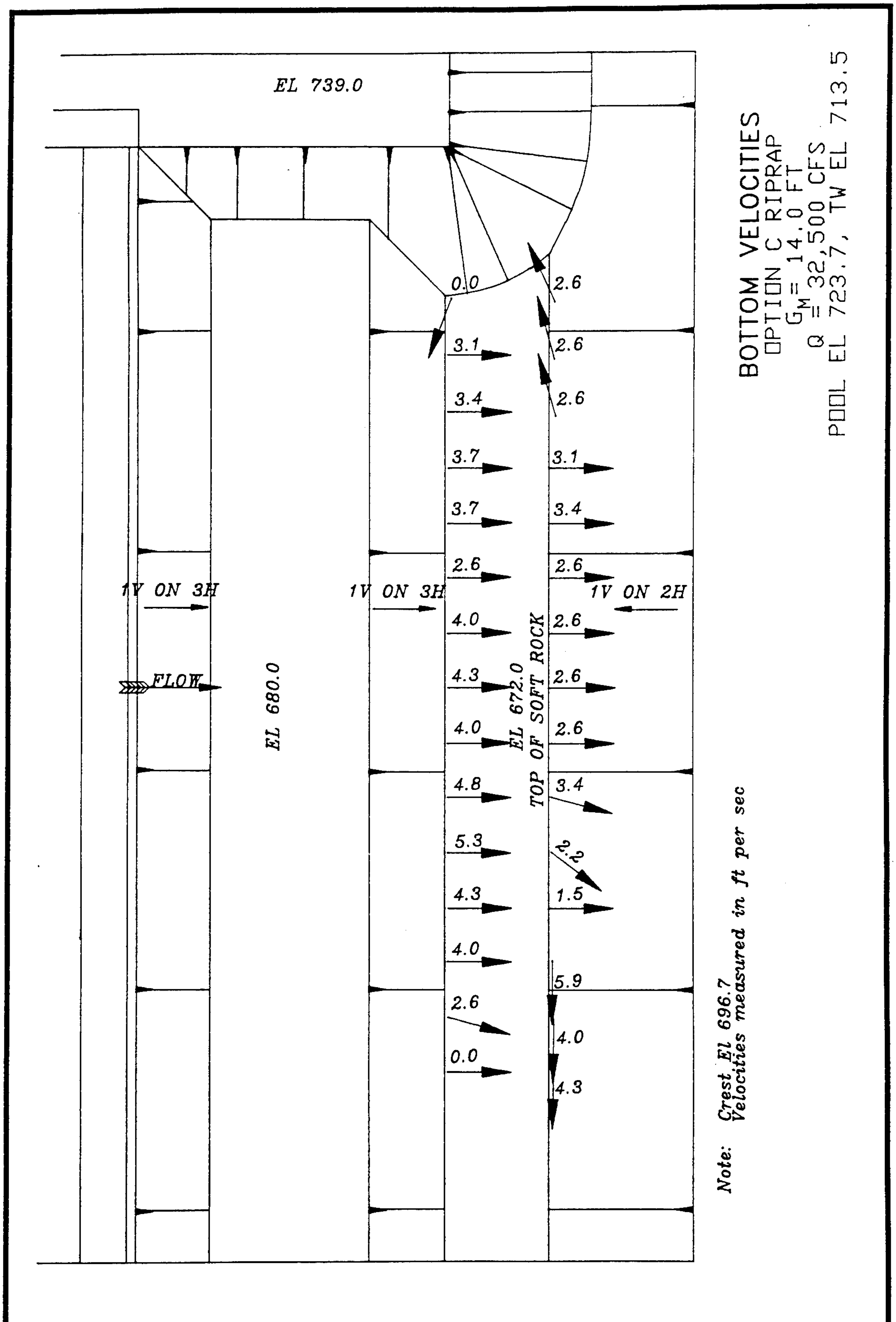
OPTION C
RIPRAP DETAIL

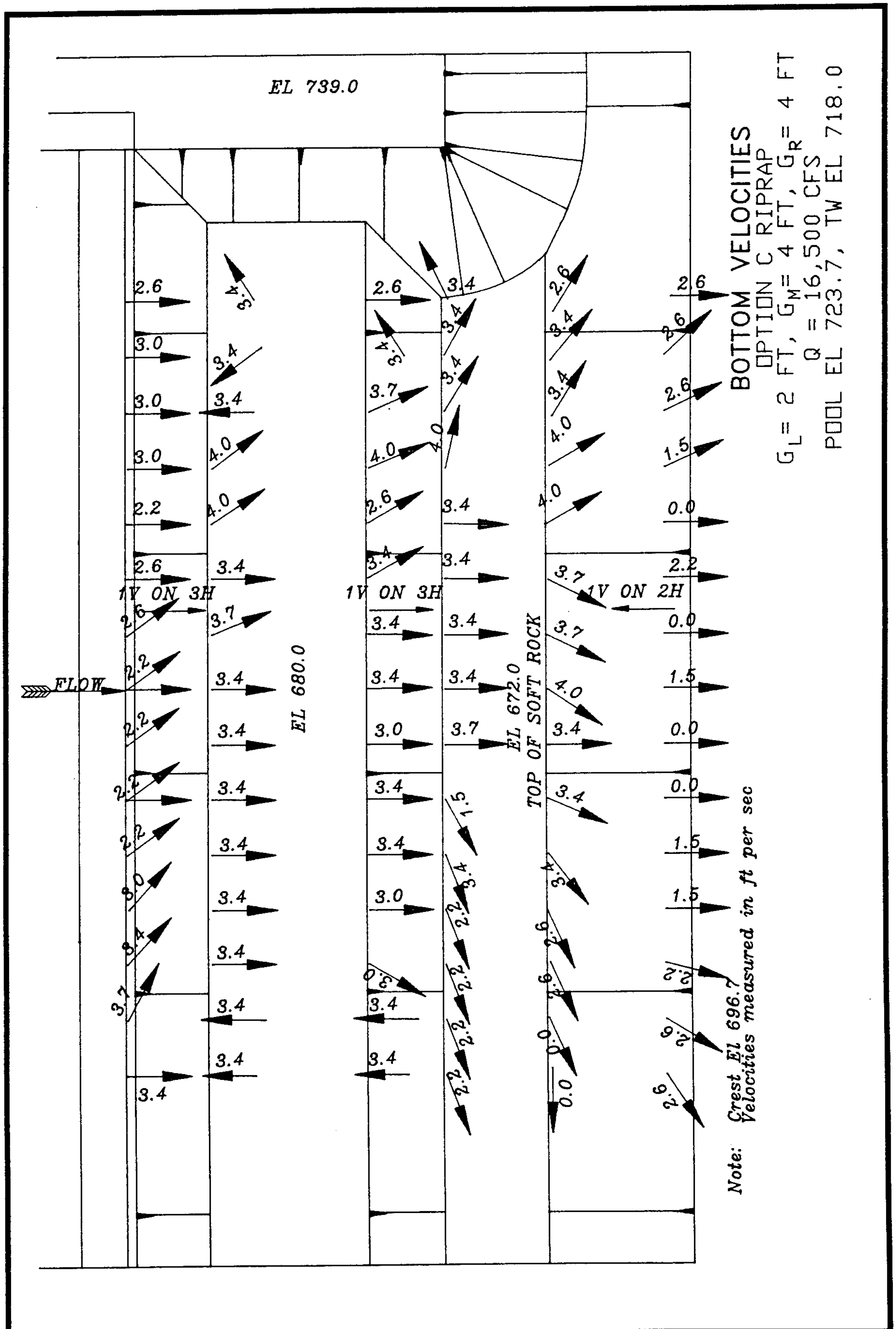

BOTTOM VELOCITIES
OPTION C RIPRAP
GL OPEN FULL
Q = 44,000 CFS
POOL EL 721.8, TW EL 712.5
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW
12.3
9.0
6.8
4.8
3.4
2.6
0.0
2.6
2.6
2.6
2.6
3.4
2.6
6.3
2.2
7.9
0.0
6.8
4.8
3.4
3.1
0.0

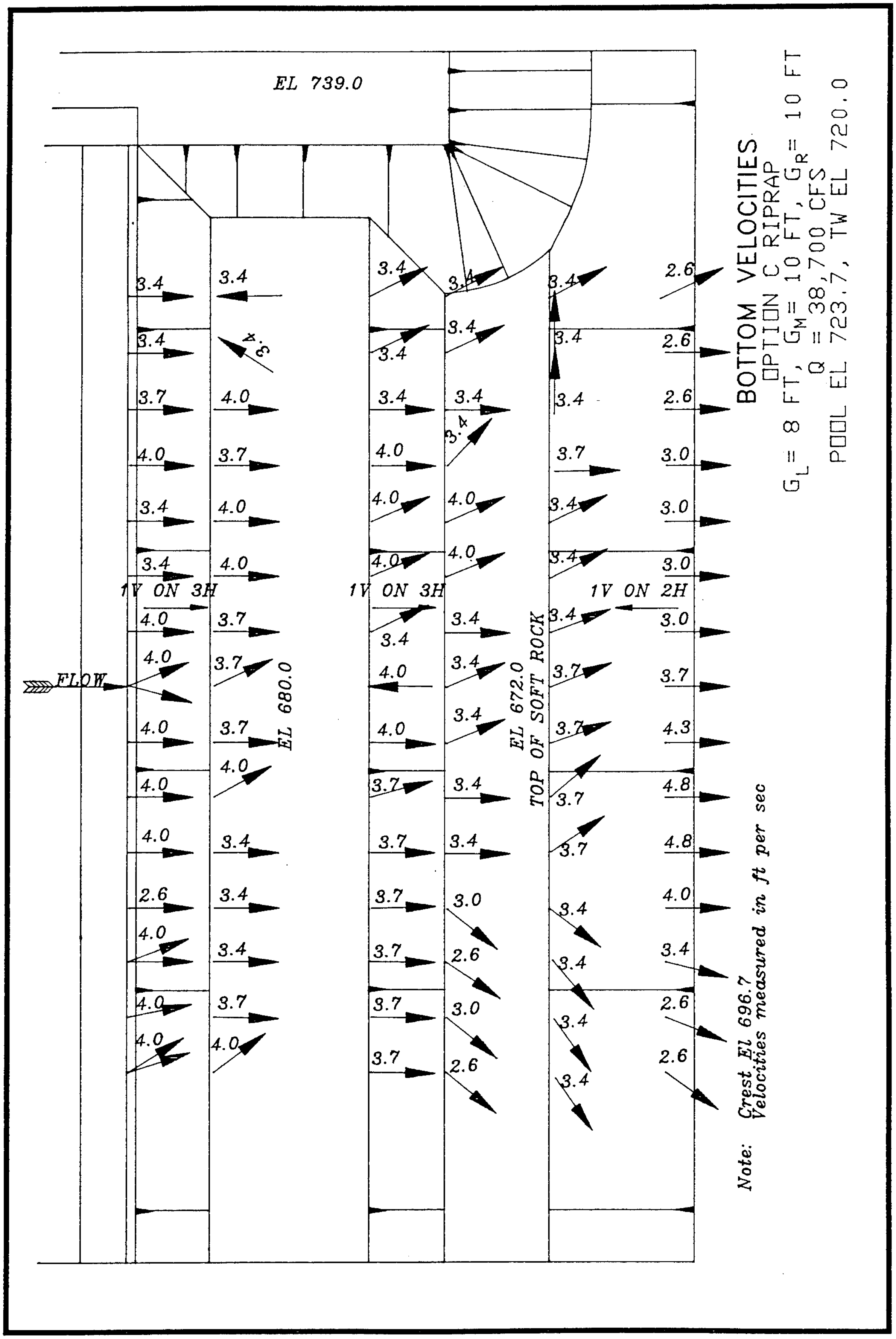


Note: Crest El 696.7
Velocities measured in ft per sec

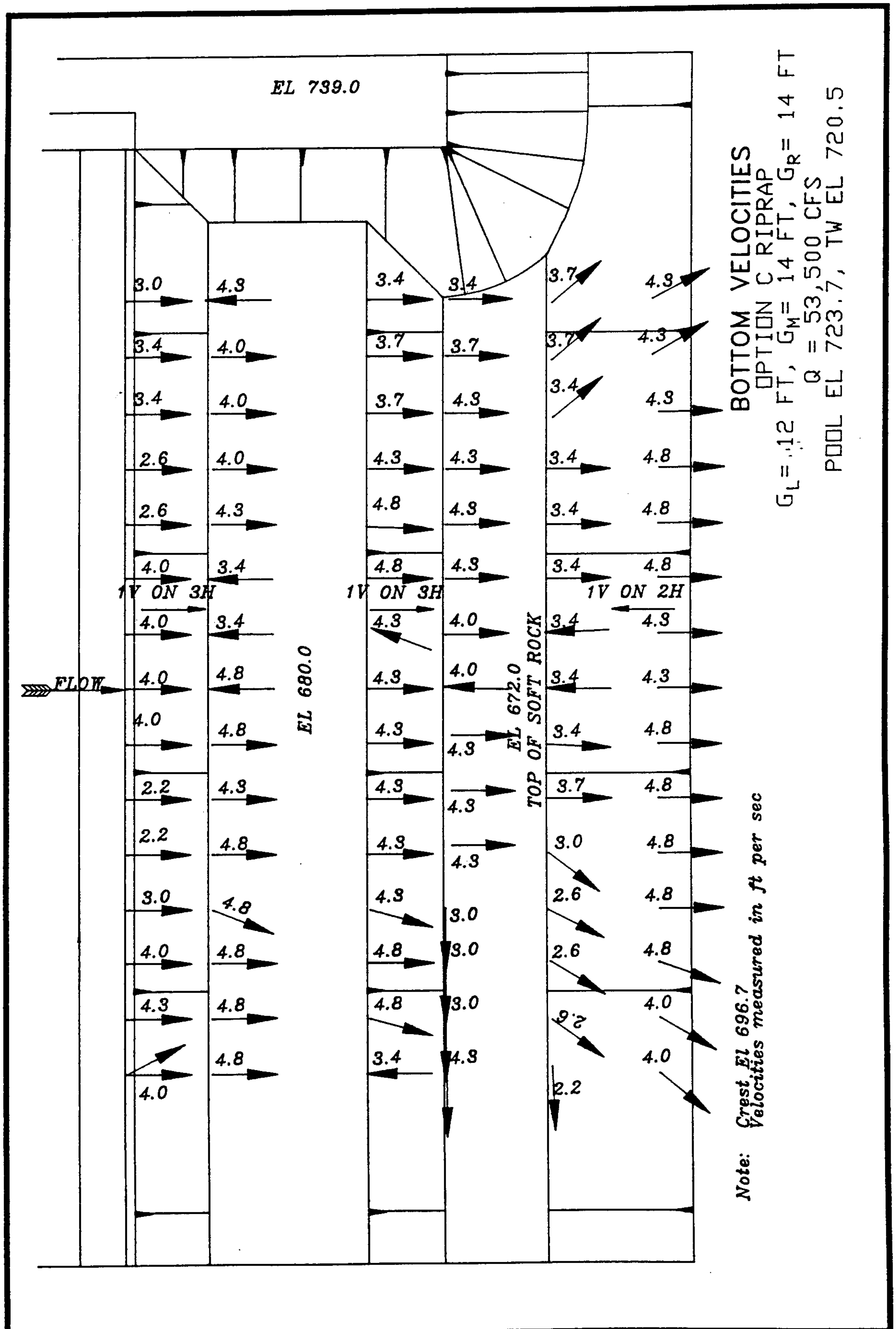
BOTTOM VELOCITIES
OPTION C RIPRAP
G_M OPEN FULL
Q = 44,000 CFS
POOL EL 721.8, TW EL 712.5

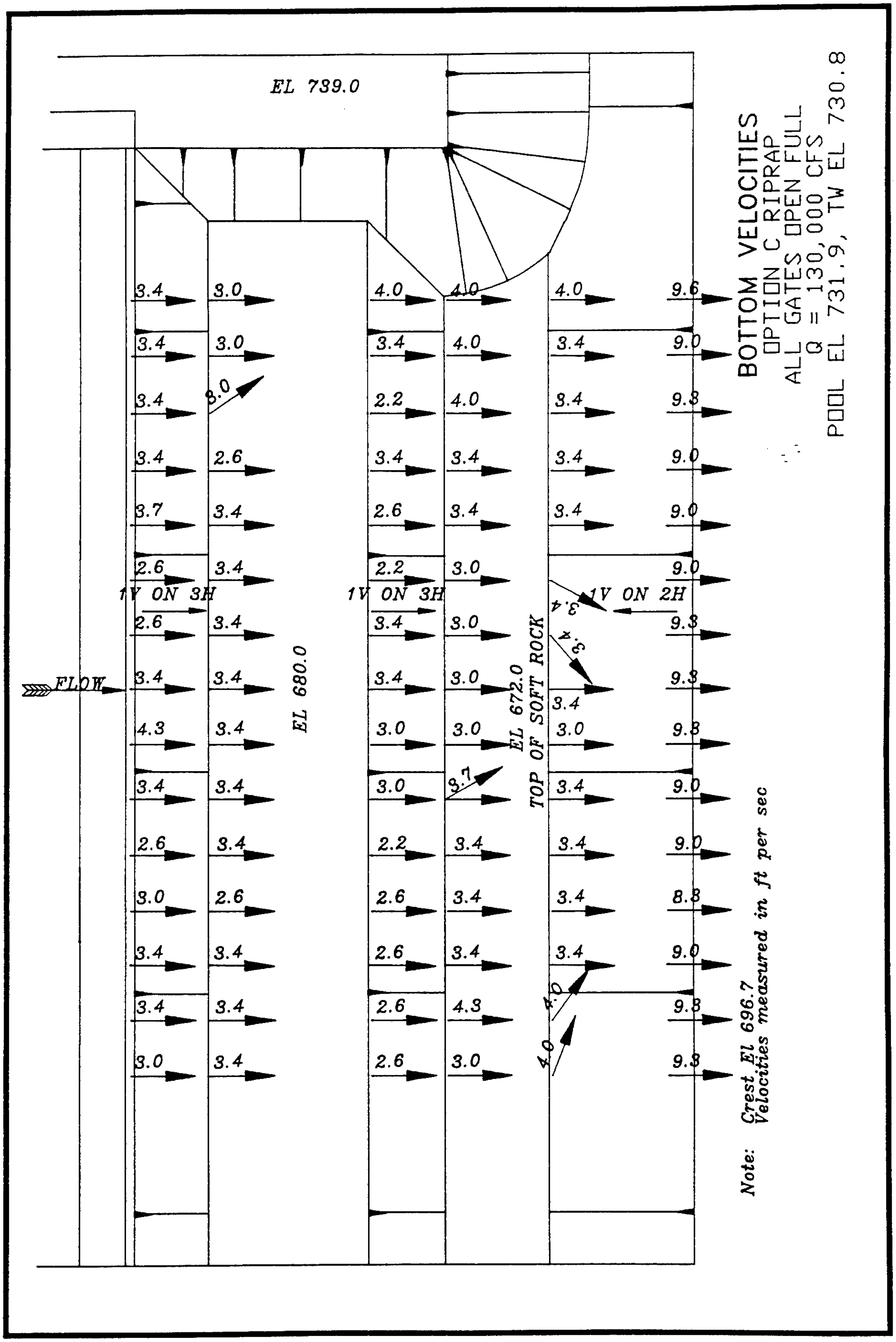

BOTTOM VELOCITIES
OPTION C RIPRAP
G_M = 14.0 FT
Q = 32,500 CFS
POOL EL 723.7, TW EL 713.5
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW
Note: Crest El 696.7
Velocities measured in ft per sec

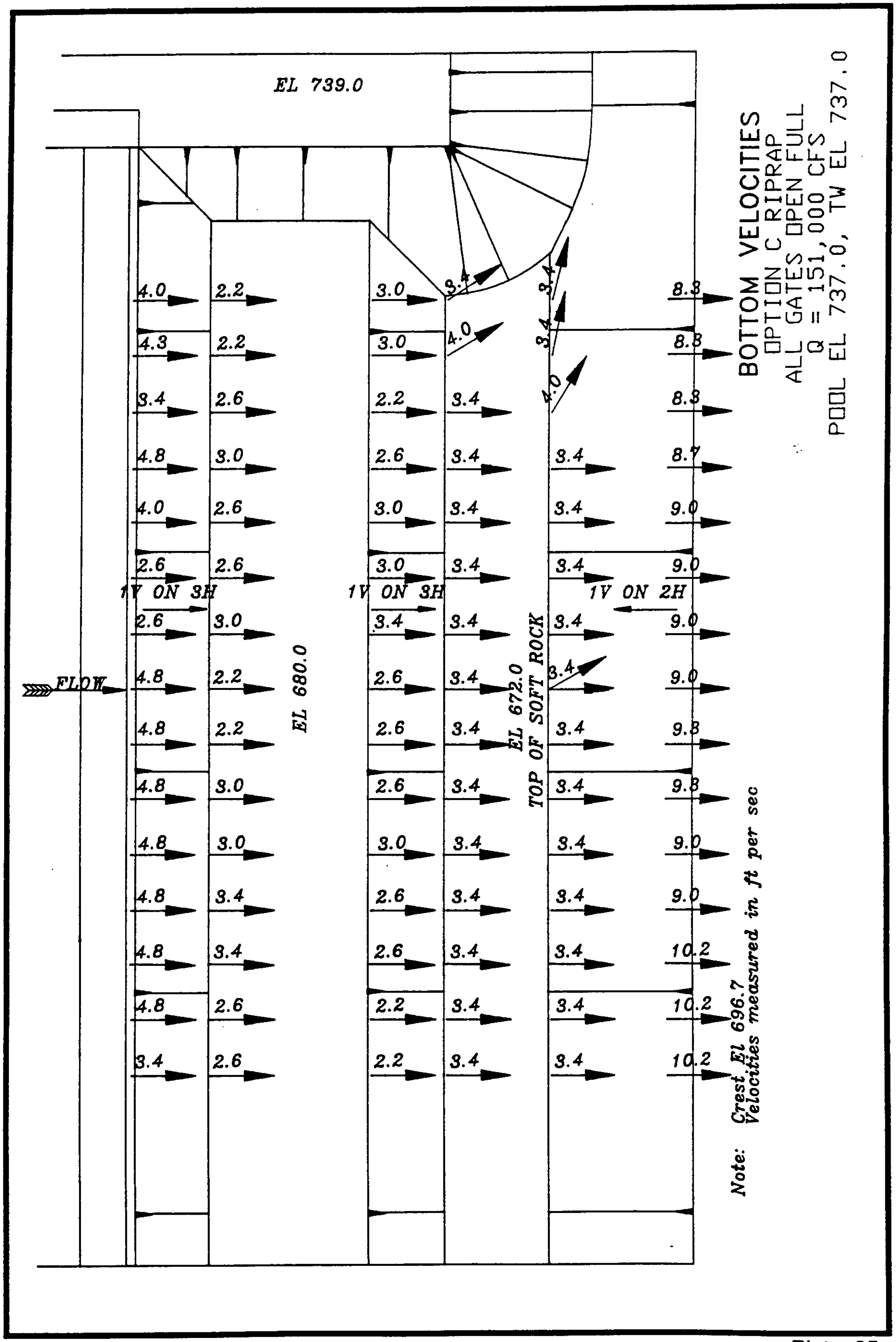

BOTTOM VELOCITIES
OPTION C RIPRAP
$G_L = 2$ FT, $G_M = 4$ FT, $G_R = 4$ FT
Q = 16,500 CFS
POOL EL 723.7, TW EL 718.0
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW
Note: Crest EL 696.7
Velocities measured in ft per sec

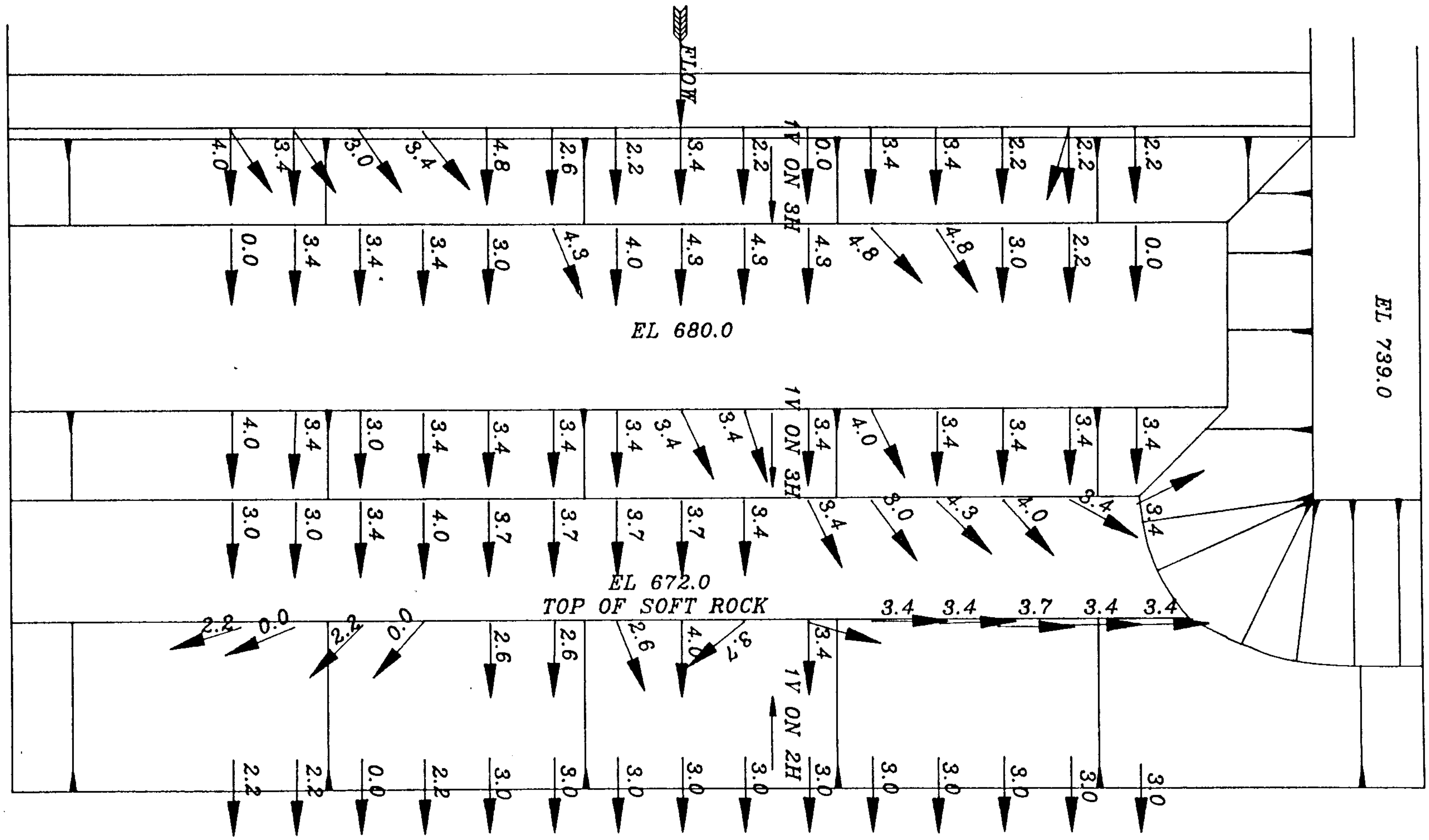


BOTTOM VELOCITIES
OPTION C RIPRAP
G_L = 8 FT, G_M = 10 FT, G_R = 10 FT
Q = 38,700 CFS
POOL EL 723.7, TW EL 720.0
EL 739.0
FLOW
1V ON 3H
1V ON 3H
1V ON 2H
EL 680.0
EL 672.0
TOP OF SOFT ROCK
Note: Crest El 696.7
Velocities measured in ft per sec


BOTTOM VELOCITIES
OPTION C RIPRAP
G_L = 12 FT, G_M = 14 FT, G_R = 14 FT
Q = 53,500 CFS
POOL EL 723.7, TW EL 720.5
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW
Note: Velocities measured in ft per sec
Crest El 696.7

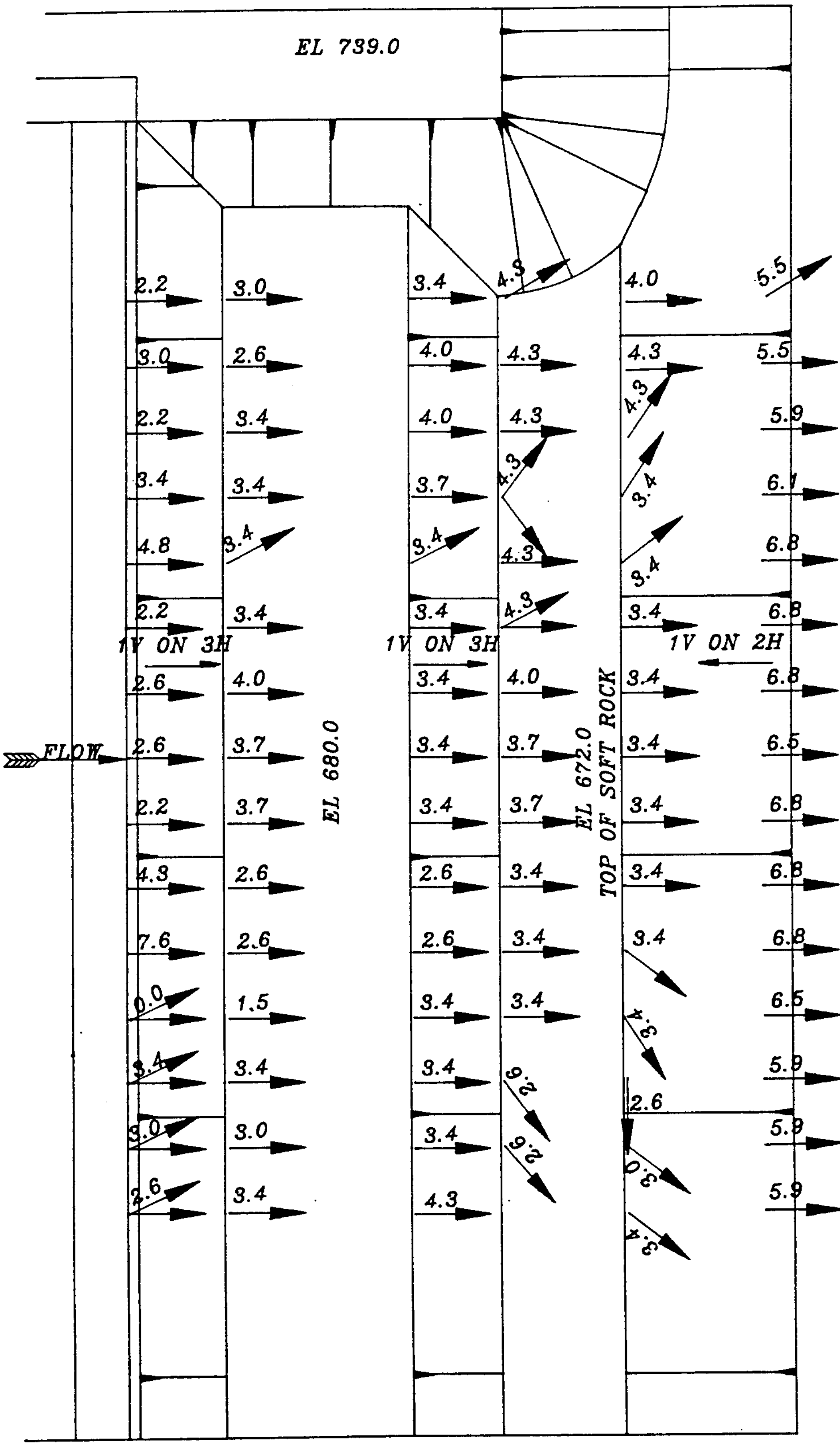

BOTTOM VELOCITIES
OPTION C RIPRAP
ALL GATES OPEN FULL
Q = 130,000 CFS
POOL EL 731.9, TW EL 730.8
Note: Crest El 696.7
Velocities measured in ft per sec
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW


BOTTOM VELOCITIES
OPTION C RIPRAP
ALL GATES OPEN FULL
Q = 151,000 CFS
POOL EL 737.0, TW EL 737.0
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW
Note: Crest El 696.7
Velocities measured in ft per sec



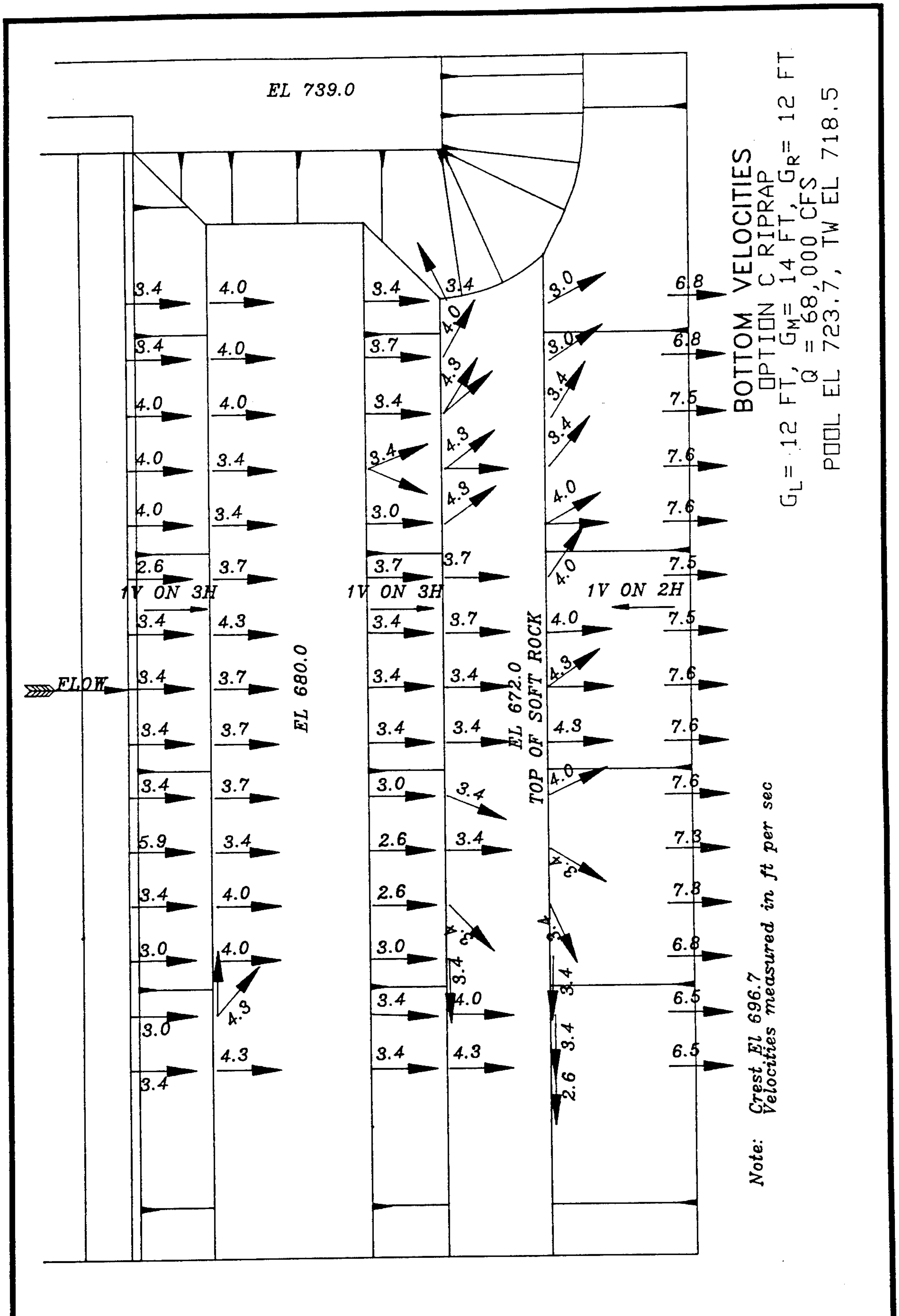
Note: Crest El 696.7
Velocities measured in ft per sec

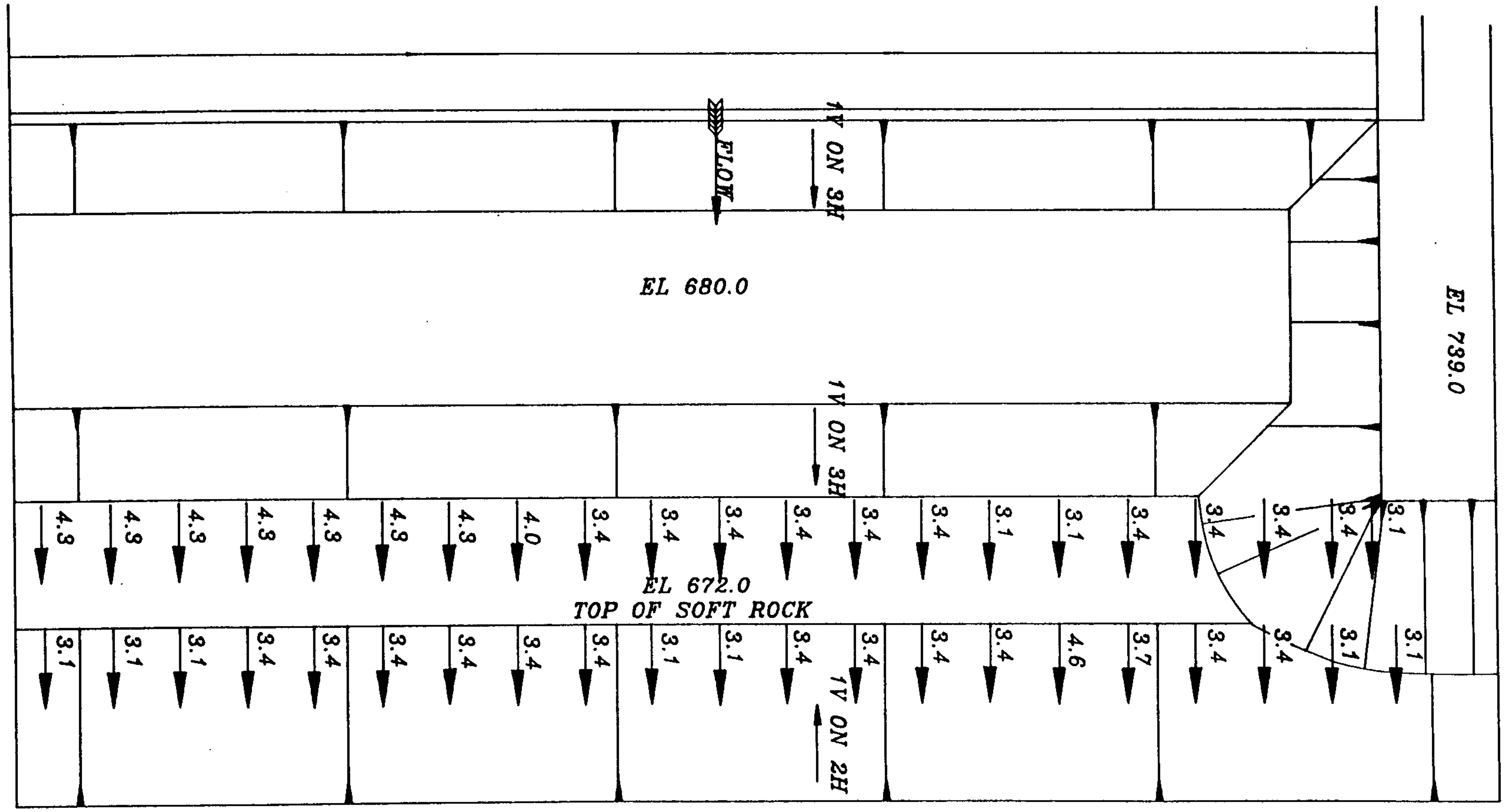
BOTTOM VELOCITIES
OPTION C RIPRAP
G_L = 2 FT, G_M = 4 FT, G_R = 2 FT
Q = 18,700 CFS
POOL EL 723.7, TW EL 712.0



BOTTOM VELOCITIES
OPTION C RIPRAP
G_L = 8 FT, G_M = 10 FT, G_R = 8 FT
Q = 52,500 CFS
POOL EL 723.7, TW EL 716.0

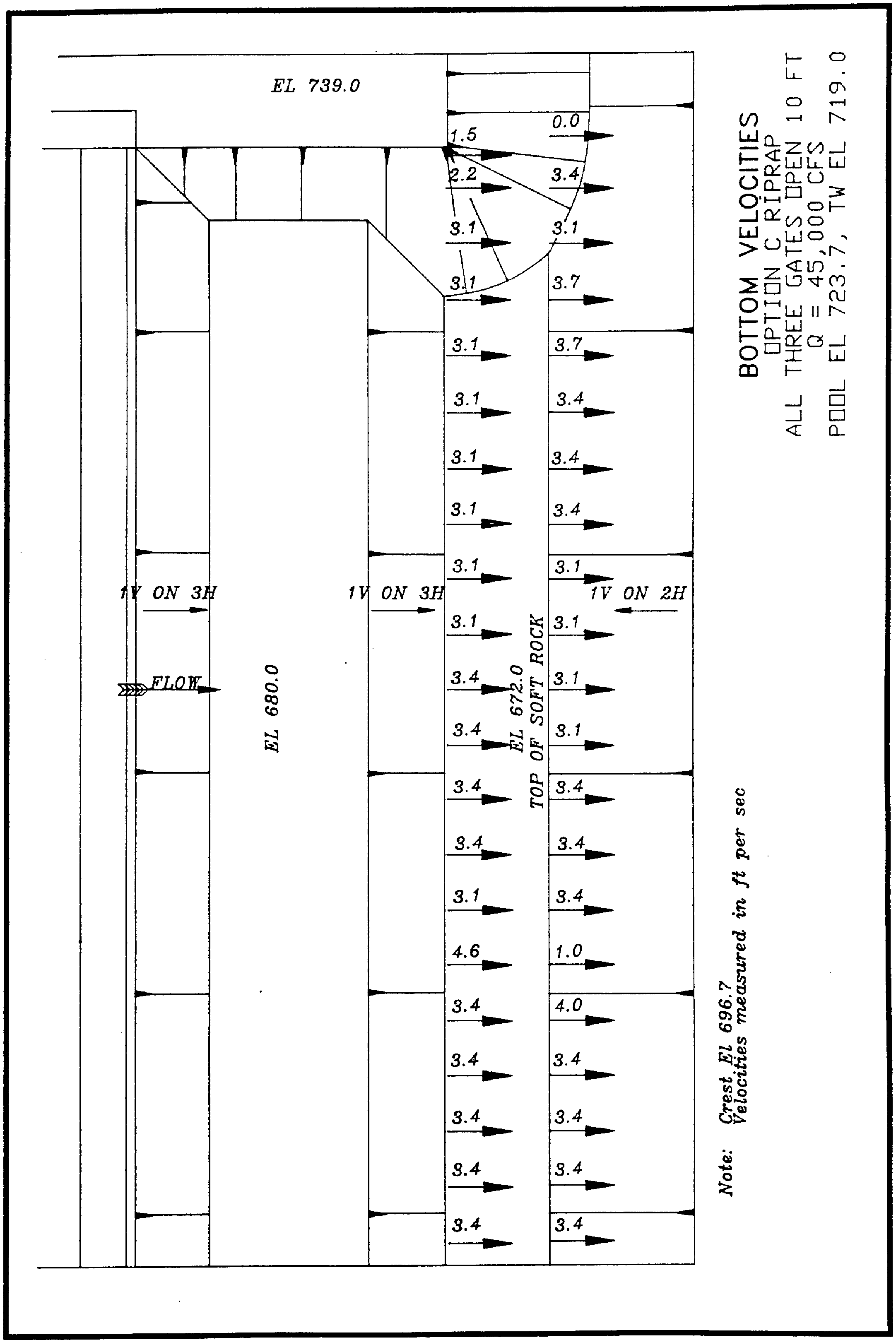
Note: Crest El 696.7
Velocities measured in ft per sec

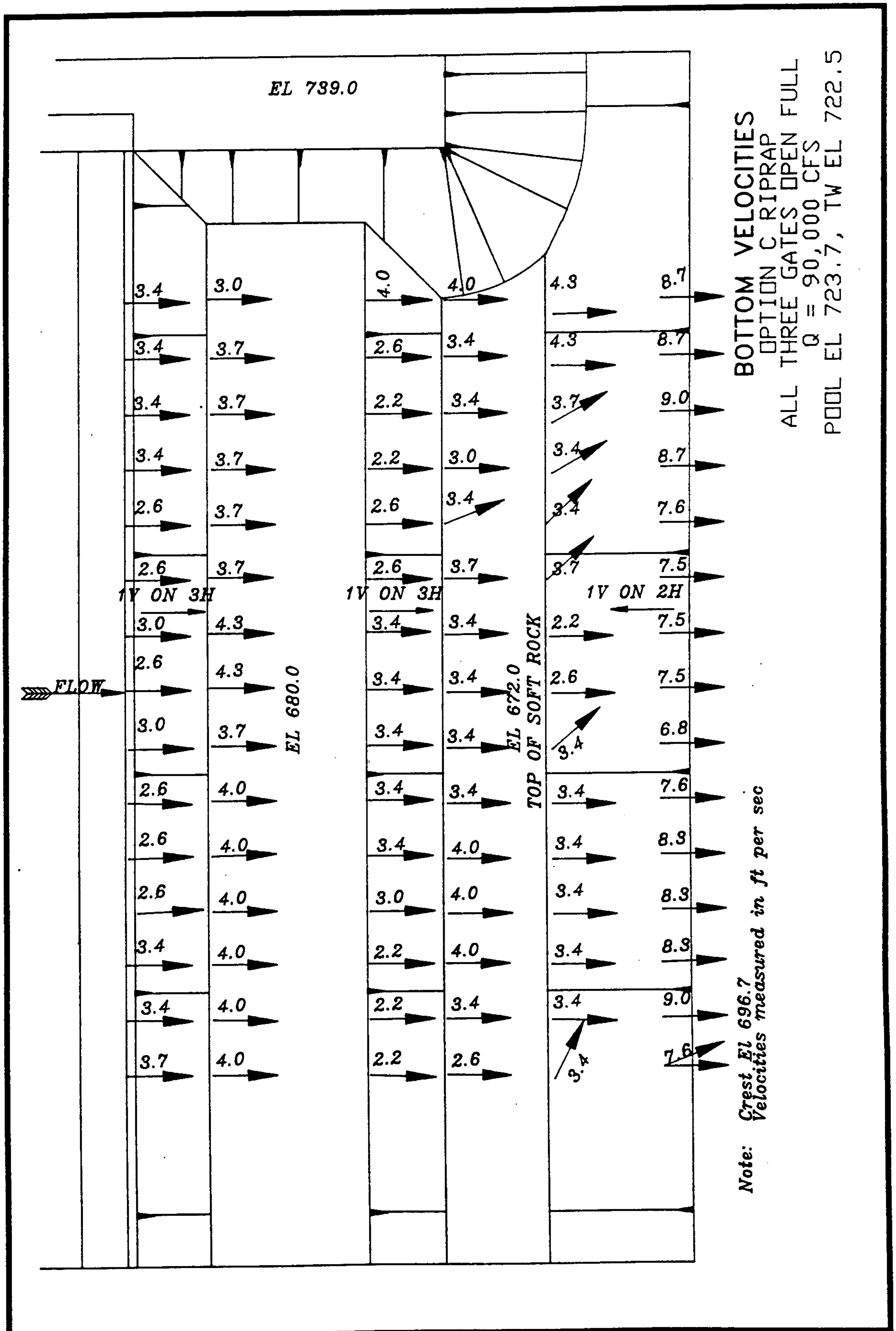

BOTTOM VELOCITIES
OPTION C RIPRAP
G_L = 12 FT, G_M = 14 FT, G_R = 12 FT
Q = 68,000 CFS
POOL EL 723.7, TW EL 718.5
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW
Note: Crest El 696.7
Velocities measured in ft per sec

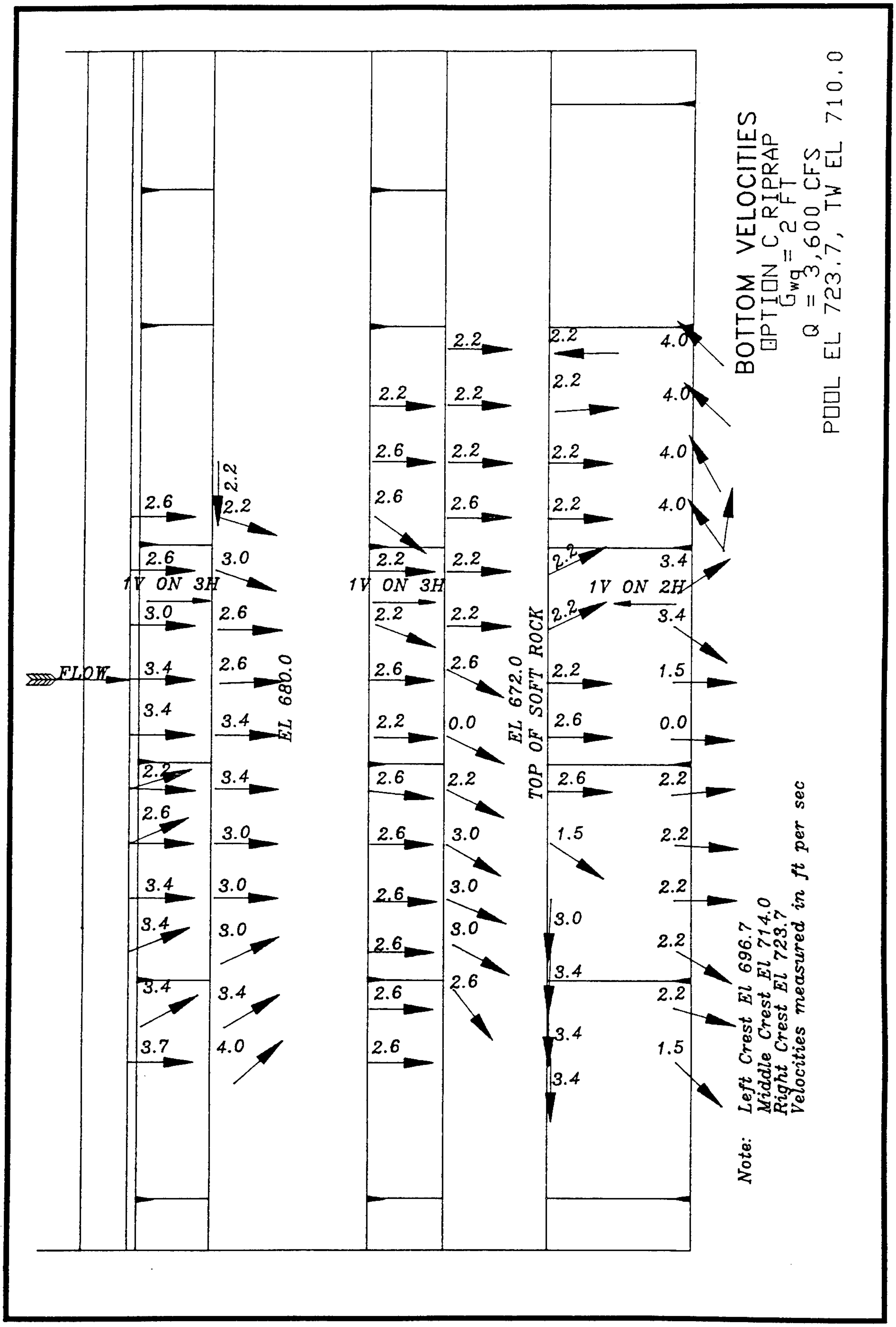


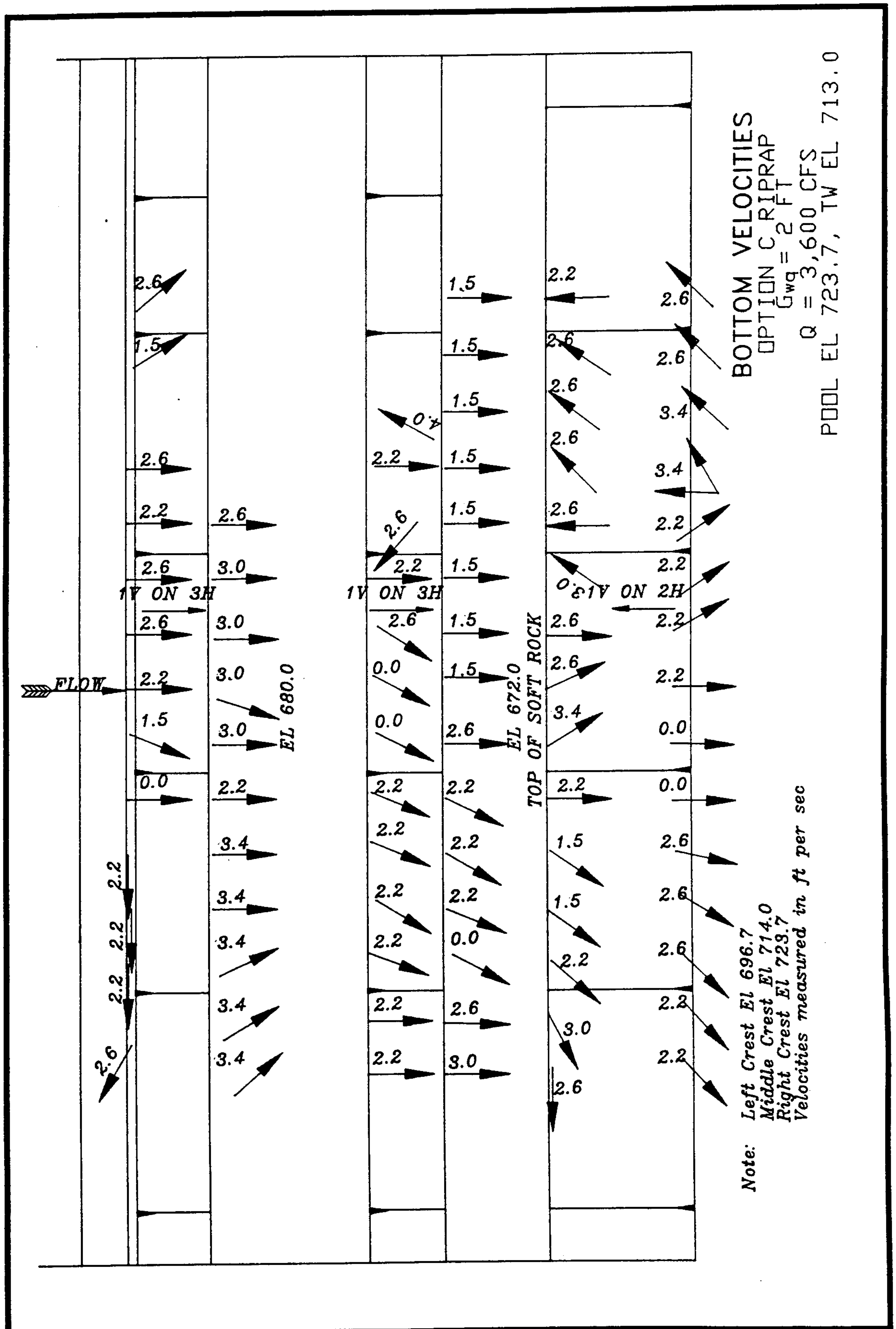
Note: Crest El 696.7
Velocities measured in ft per seo

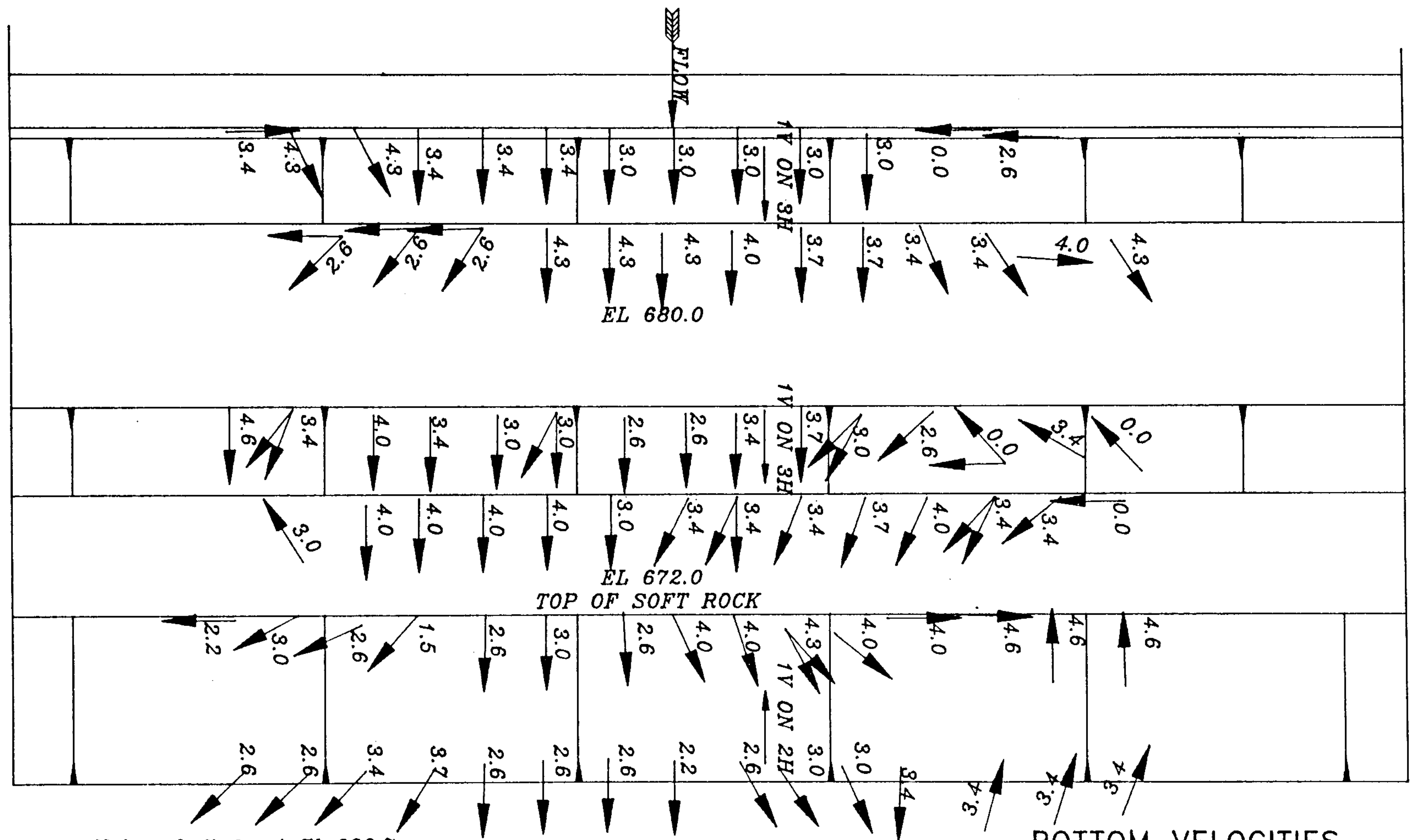
BOTTOM VELOCITIES
OPTION C RIPRAP
ALL THREE GATES OPEN 4 FT
Q = 25,000 CFS
POOL EL 723.7, TW EL 715.0


BOTTOM VELOCITIES
OPTION C RIPRAP
ALL THREE GATES OPEN 10 FT
Q = 45,000 CFS
POOL EL 723.7, TW EL 719.0
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW
1.5
2.2
3.1
3.1
3.1
3.1
3.1
3.1
3.1
3.1
3.4
3.4
3.4
3.4
3.1
4.6
3.4
3.4
3.4
3.4
3.4
0.0
3.4
3.1
3.7
3.7
3.4
3.4
3.4
3.1
3.1
3.1
3.1
3.4
3.4
3.4
1.0
4.0
3.4
3.4
3.4
3.4
Note: Crest El 696.7
Velocities measured in ft per sec


BOTTOM VELOCITIES
OPTION C RIPRAP
ALL THREE GATES OPEN FULL
Q = 90,000 CFS
POOL EL 723.7, TW EL 722.5
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW
Note: Crest El 696.7
Velocities measured in ft per sec

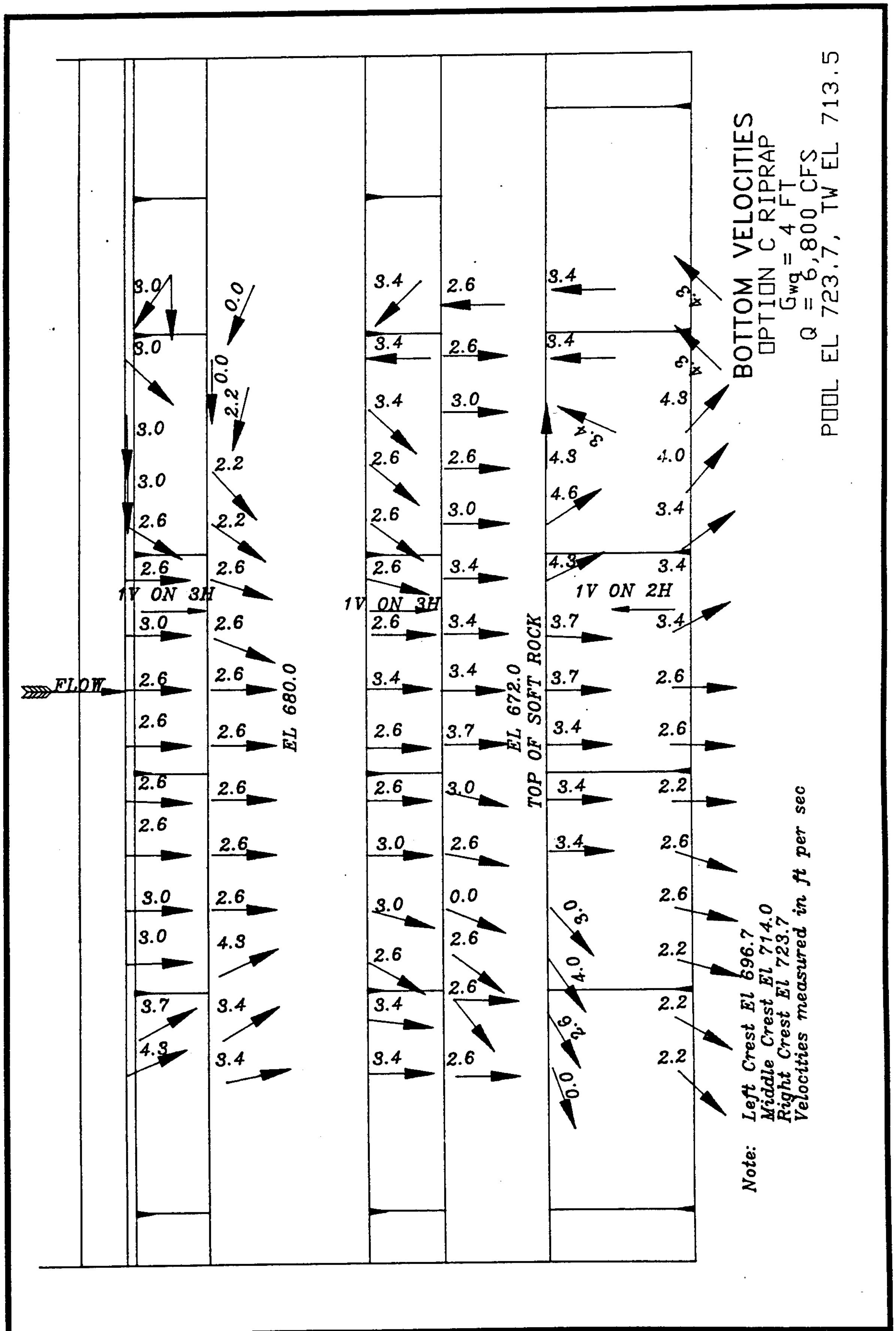

BOTTOM VELOCITIES
OPTION C RIPRAP
G_{wq} = 2 FT
Q = 3,600 CFS
POOL EL 723.7, TW EL 710.0
FLOW
1V ON 3H
1V ON 3H
1V ON 2H
EL 680.0
EL 672.0
TOP OF SOFT ROCK
Note: Left Crest El 696.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

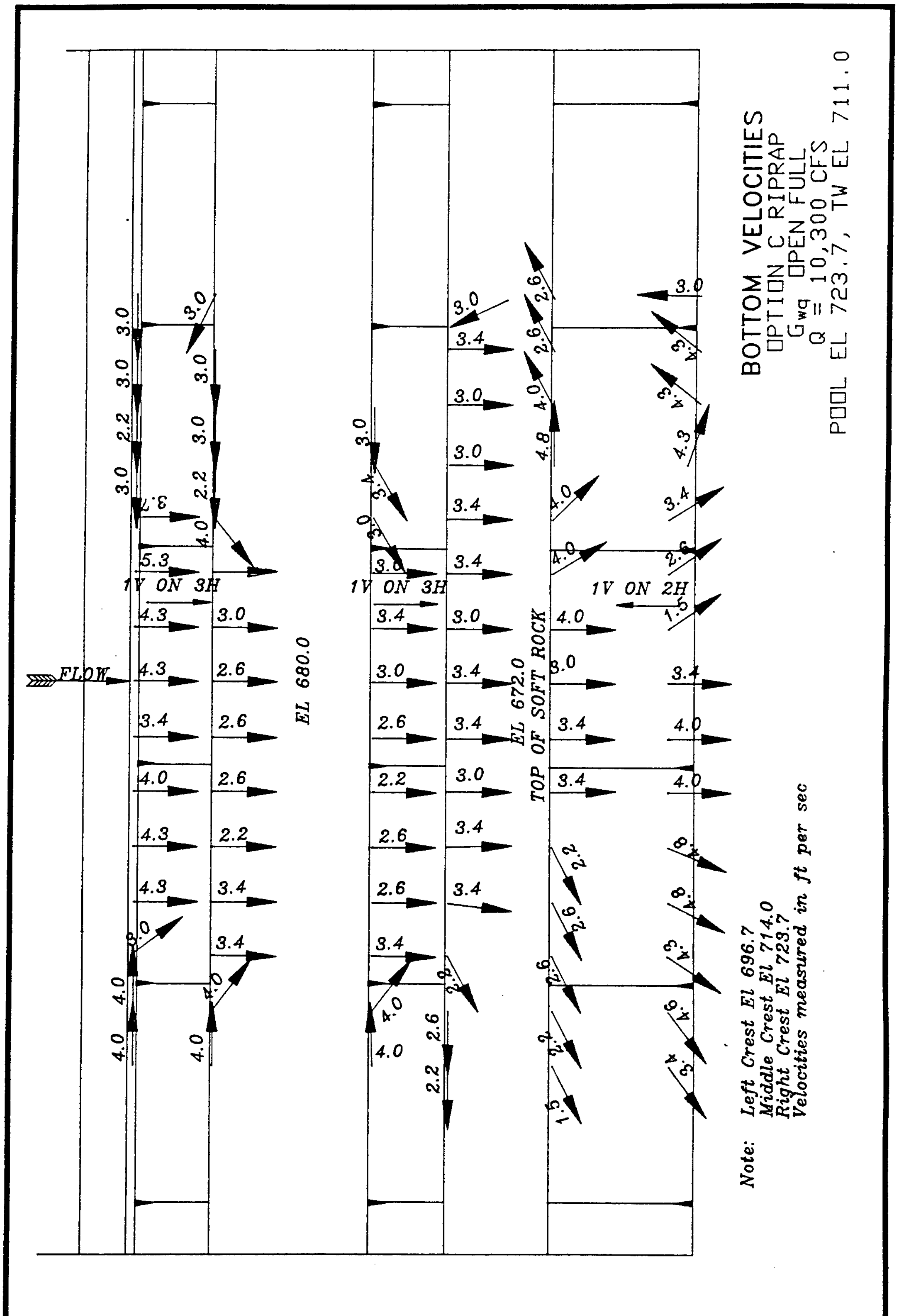

BOTTOM VELOCITIES
OPTION C RIPRAP
G_{wq} = 2 FT
Q = 3,600 CFS
POOL EL 723.7, TW EL 713.0
FLOW
1V ON 3H
1V ON 3H
1V ON 2H
EL 680.0
EL 672.0
TOP OF SOFT ROCK
Note: Left Crest El 696.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

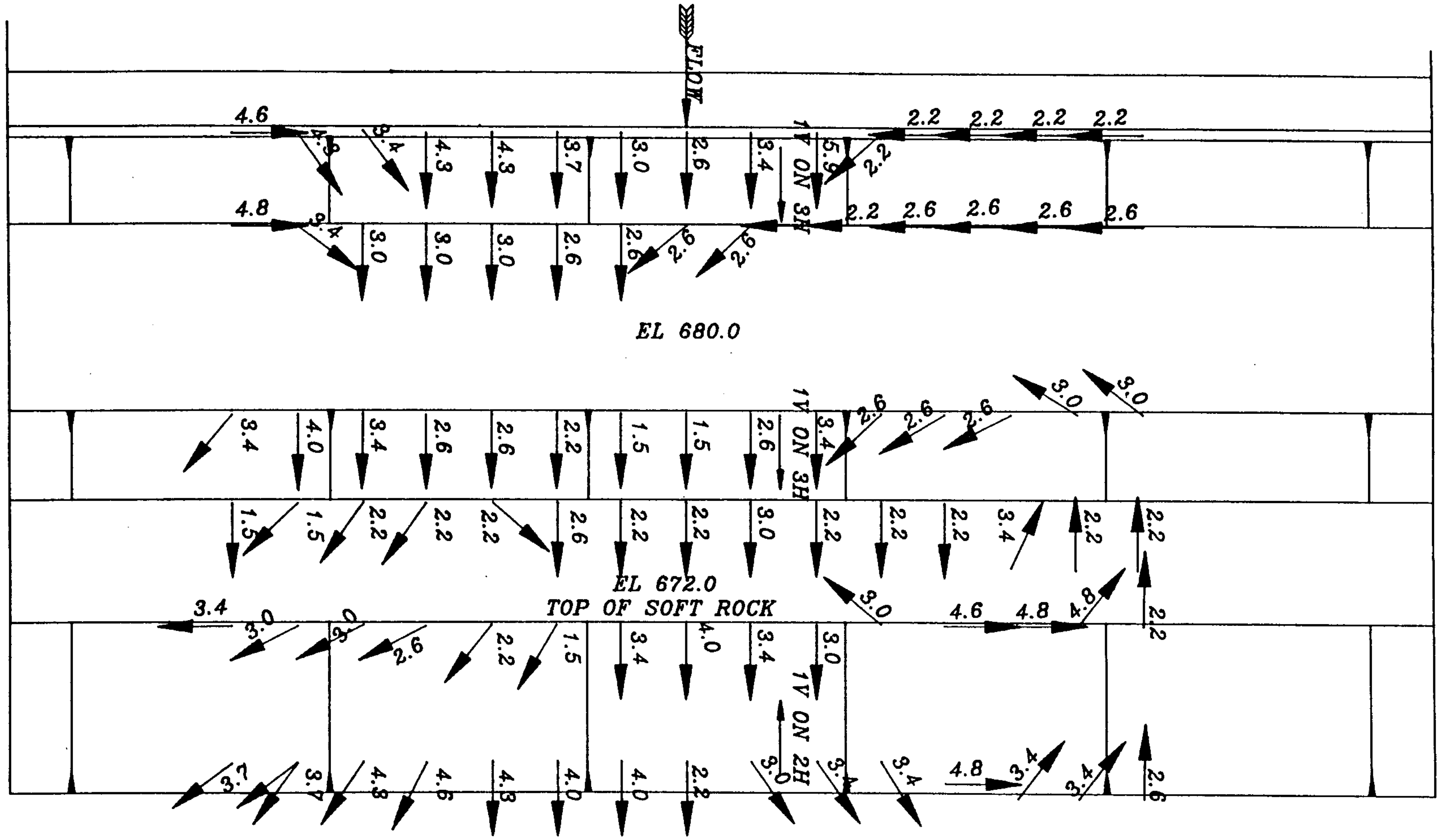


Note: Left Crest El 696.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION C RIPRAP
G_{wq} = 4 FT
Q = 7,000 CFS
POOL EL 723.7, TW EL 710.5

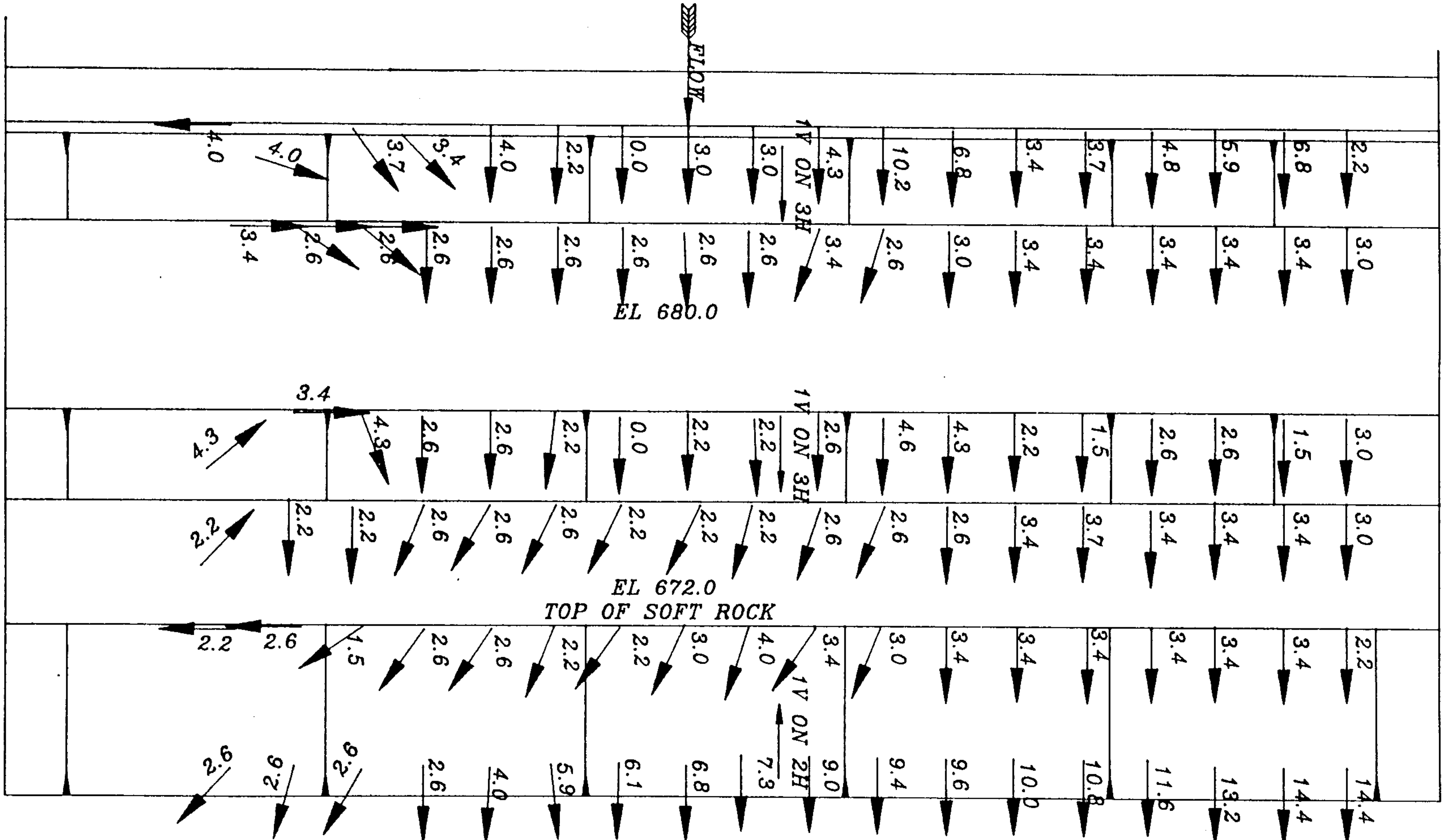

BOTTOM VELOCITIES
OPTION C RIPRAP
G_{wg} = 4 FT
Q = 6,800 CFS
POOL EL 723.7, TW EL 713.5
FLOW
1V ON 3H
1V ON 3H
1V ON 2H
EL 680.0
EL 672.0
TOP OF SOFT ROCK
Note: Left Crest El 696.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec


BOTTOM VELOCITIES
OPTION C RIPRAP
Gwq OPEN FULL
Q = 10,300 CFS
POOL EL 723.7, TW EL 711.0
FLOW
1V ON 3H
1V ON 3H
1V ON 2H
EL 680.0
EL 672.0
TOP OF SOFT ROCK
Note: Left Crest El 696.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec



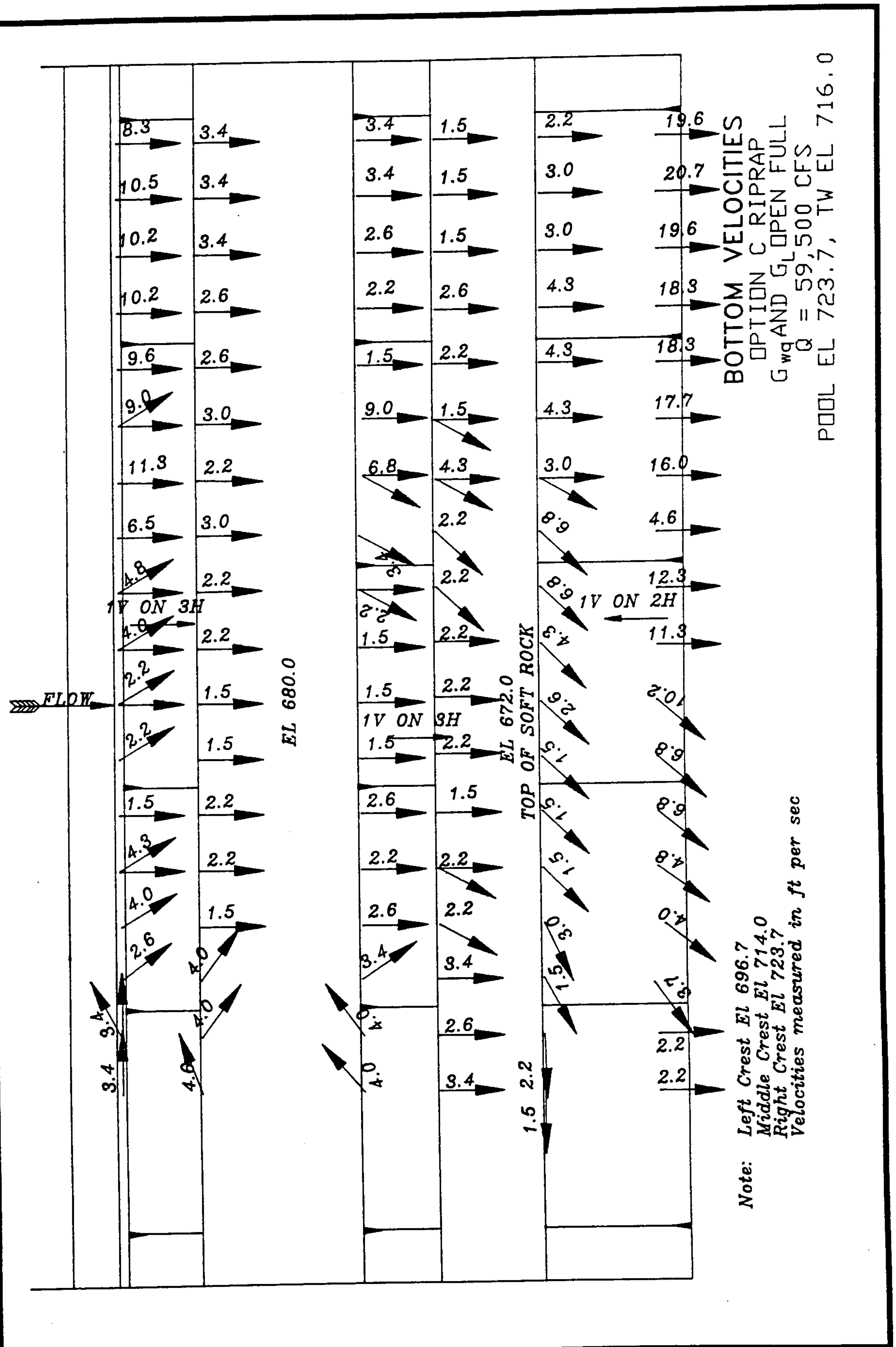
Note: Left Crest El 696.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

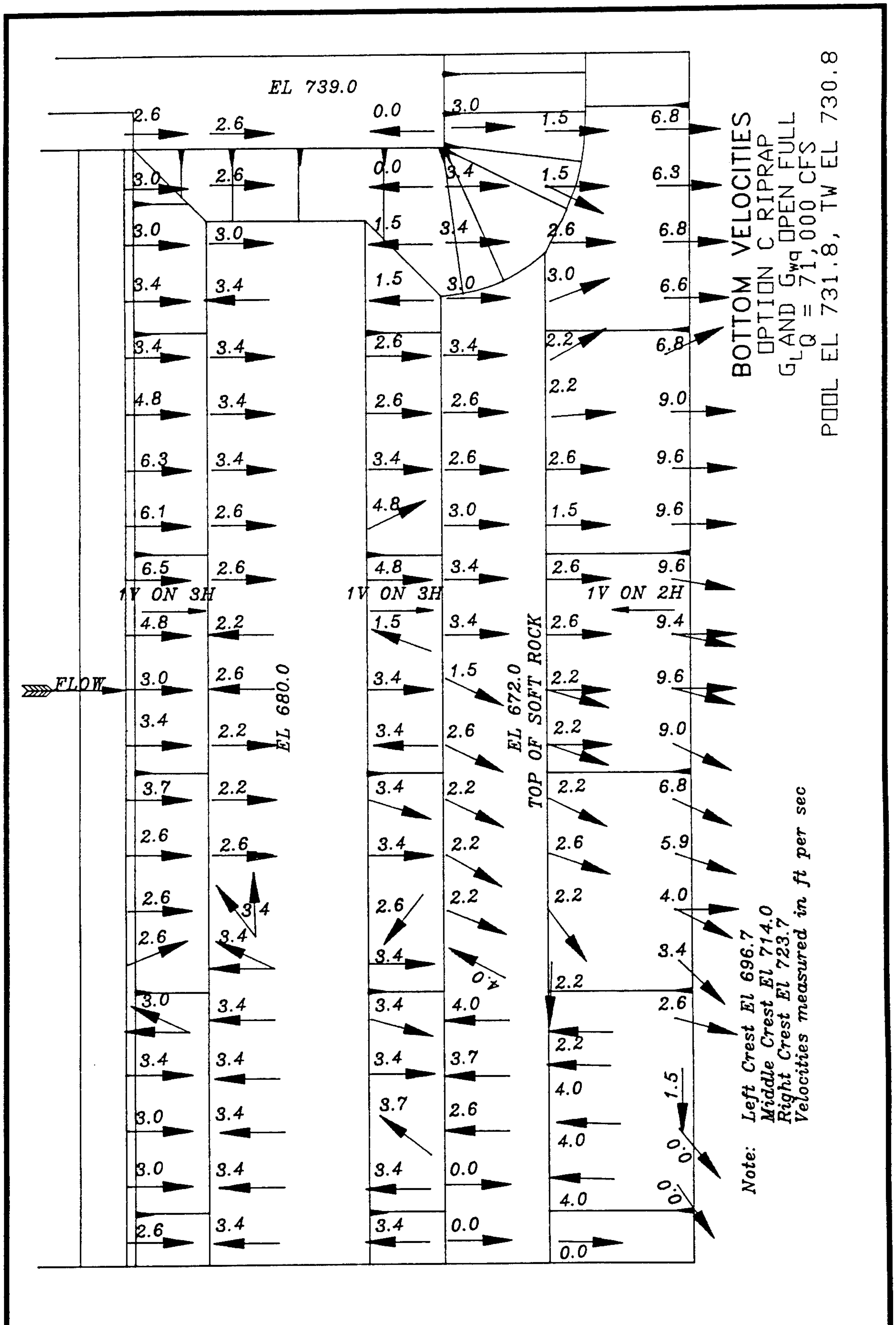
BOTTOM VELOCITIES
OPTION C RIPRAP
G_{wq} OPEN FULL
Q = 10,300 CFS
POOL EL 723.7, TW EL 714.0

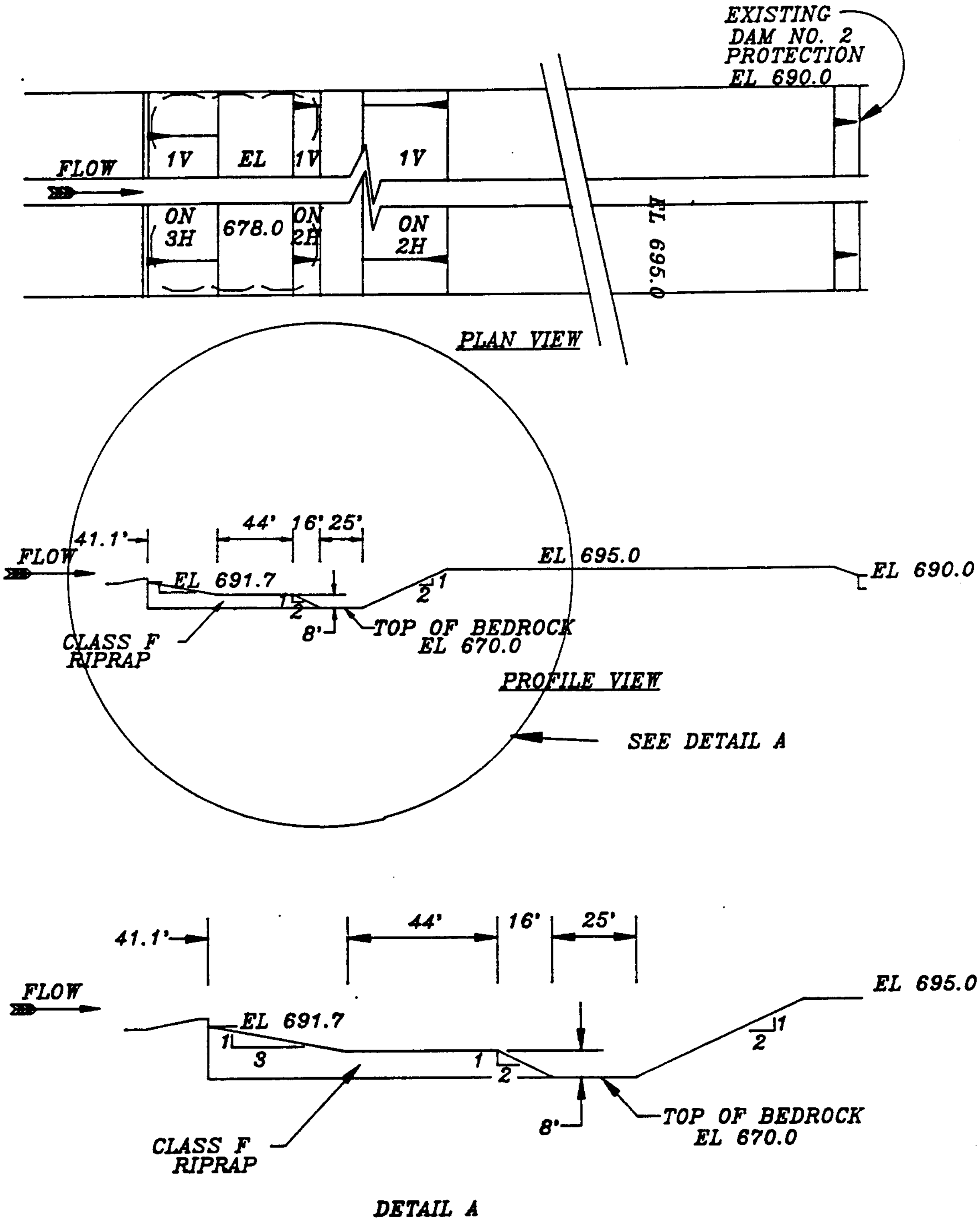


Note: *Left Crest El 696.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

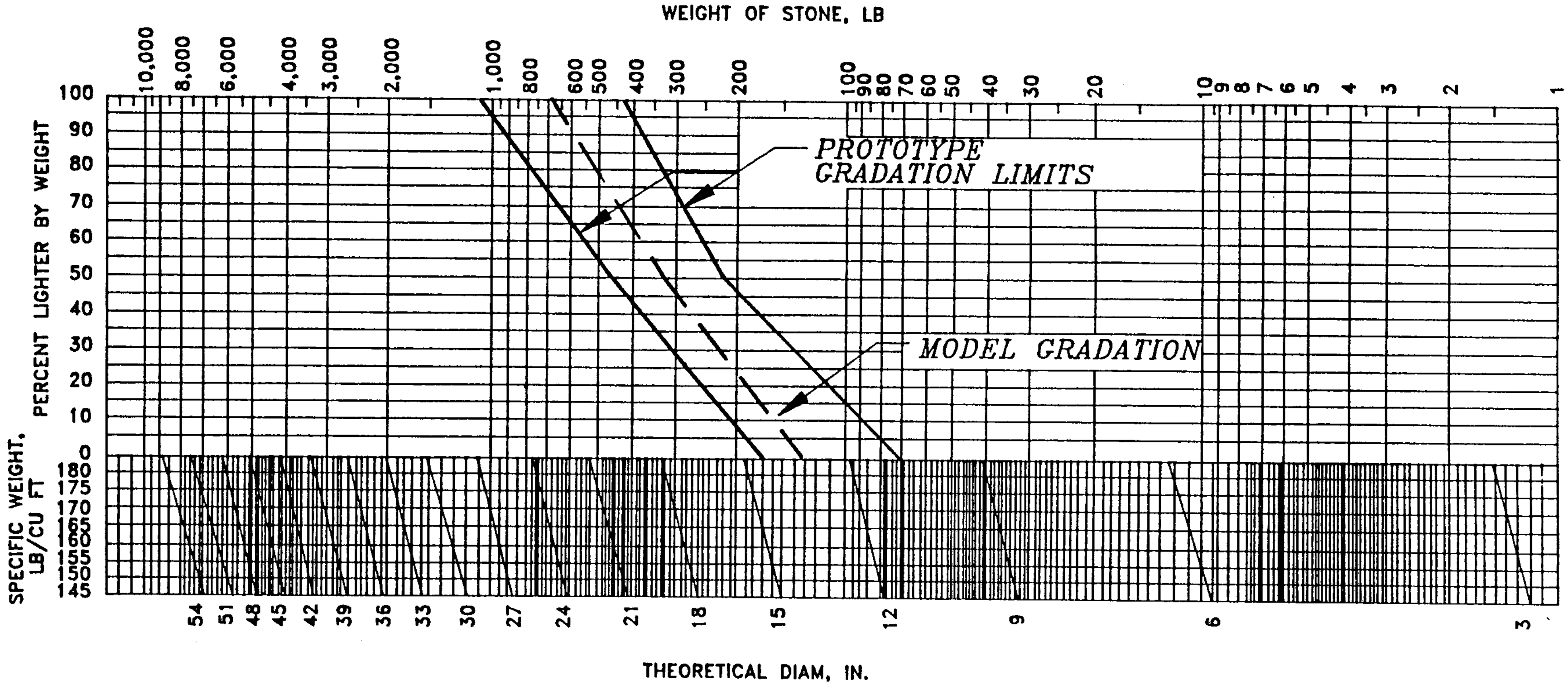
BOTTOM VELOCITIES
OPTION C RIPRAP
G_L = 14.0 AND G_{wq} OPEN FULL
Q = 42,000 CFS
POOL EL 723.7, TW EL 715.0


BOTTOM VELOCITIES
OPTION C RIPRAP
G_{wq} AND G_L OPEN FULL
Q = 59,500 CFS
POOL EL 723.7, TW EL 716.0
FLOW
1V ON 3H
1V ON 3H
1V ON 2H
EL 680.0
EL 672.0
TOP OF SOFT ROCK
Note: Left Crest El 696.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec


BOTTOM VELOCITIES
OPTION C RIPRAP
G$_L$ AND G$_{wq}$ OPEN FULL
Q = 71,000 CFS
POOL EL 731.8, TW EL 730.8
EL 739.0
FLOW
1V ON 3H
1V ON 3H
1V ON 2H
EL 680.0
EL 672.0
TOP OF SOFT ROCK
Note: Left Crest El 696.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec



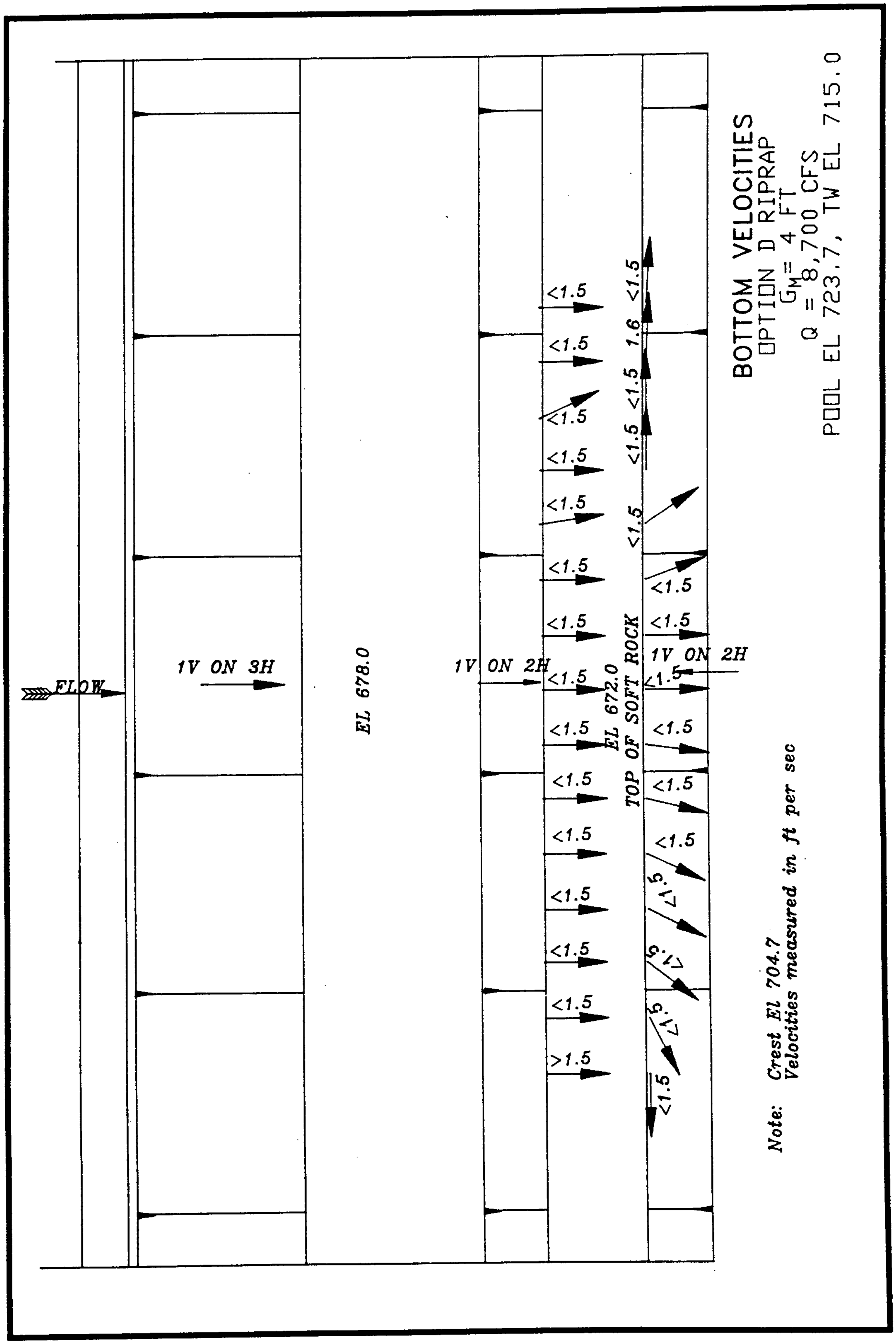
OPTION D
RIPRAP DETAIL

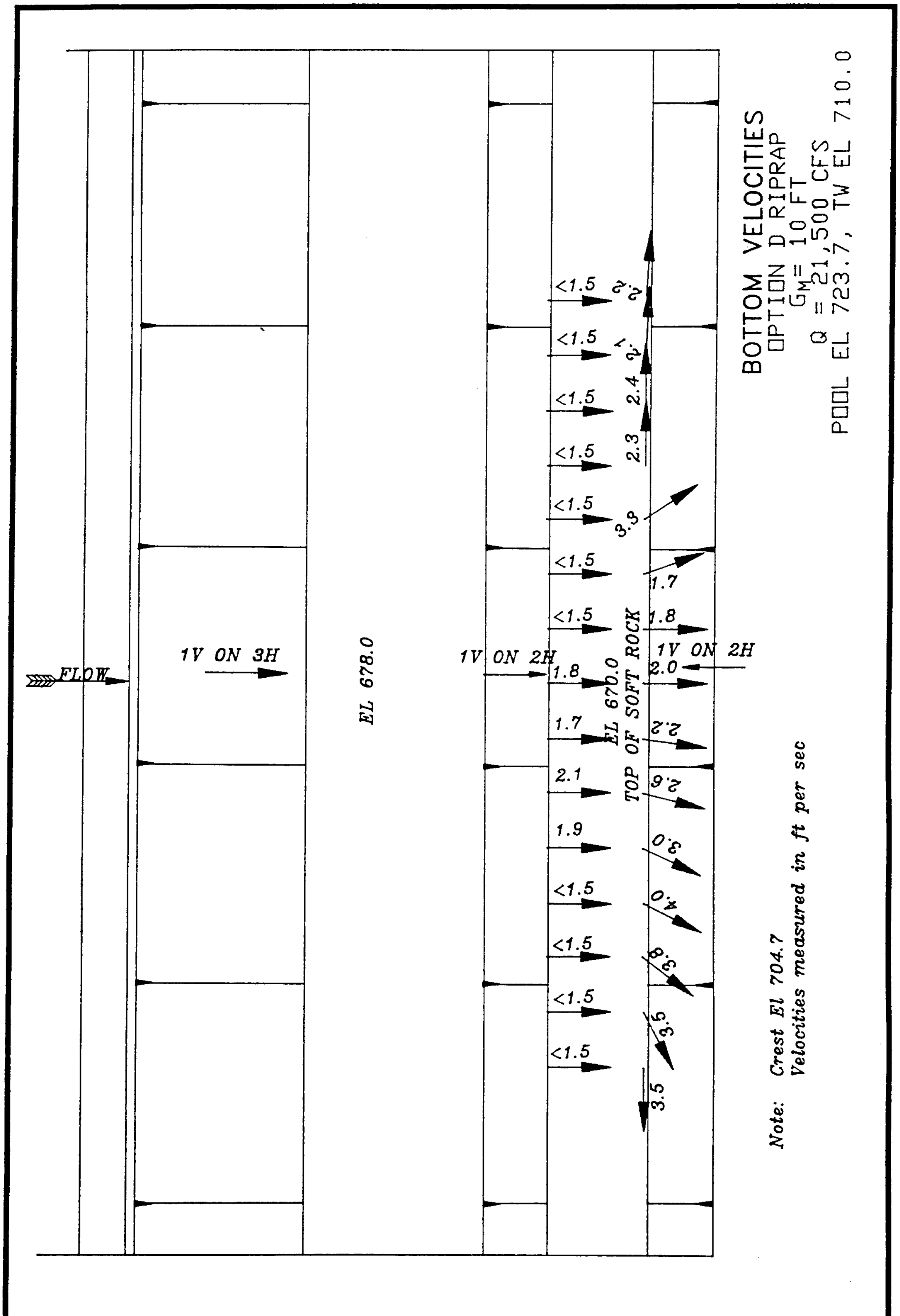


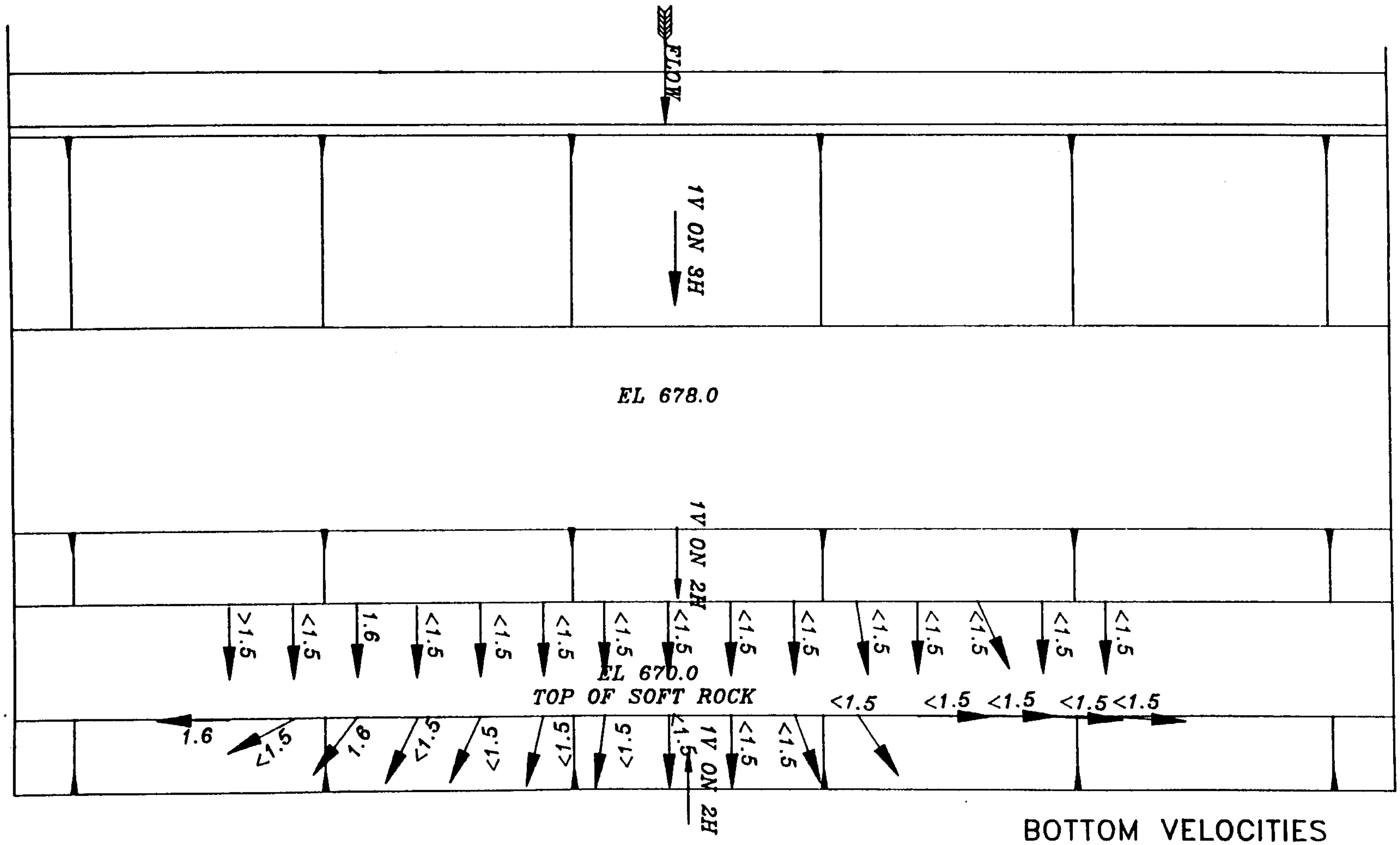
SPECIFIC WEIGHT OF STONE 165 LB/CU FT

RIPRAP GRADATION CURVES

CLASS F

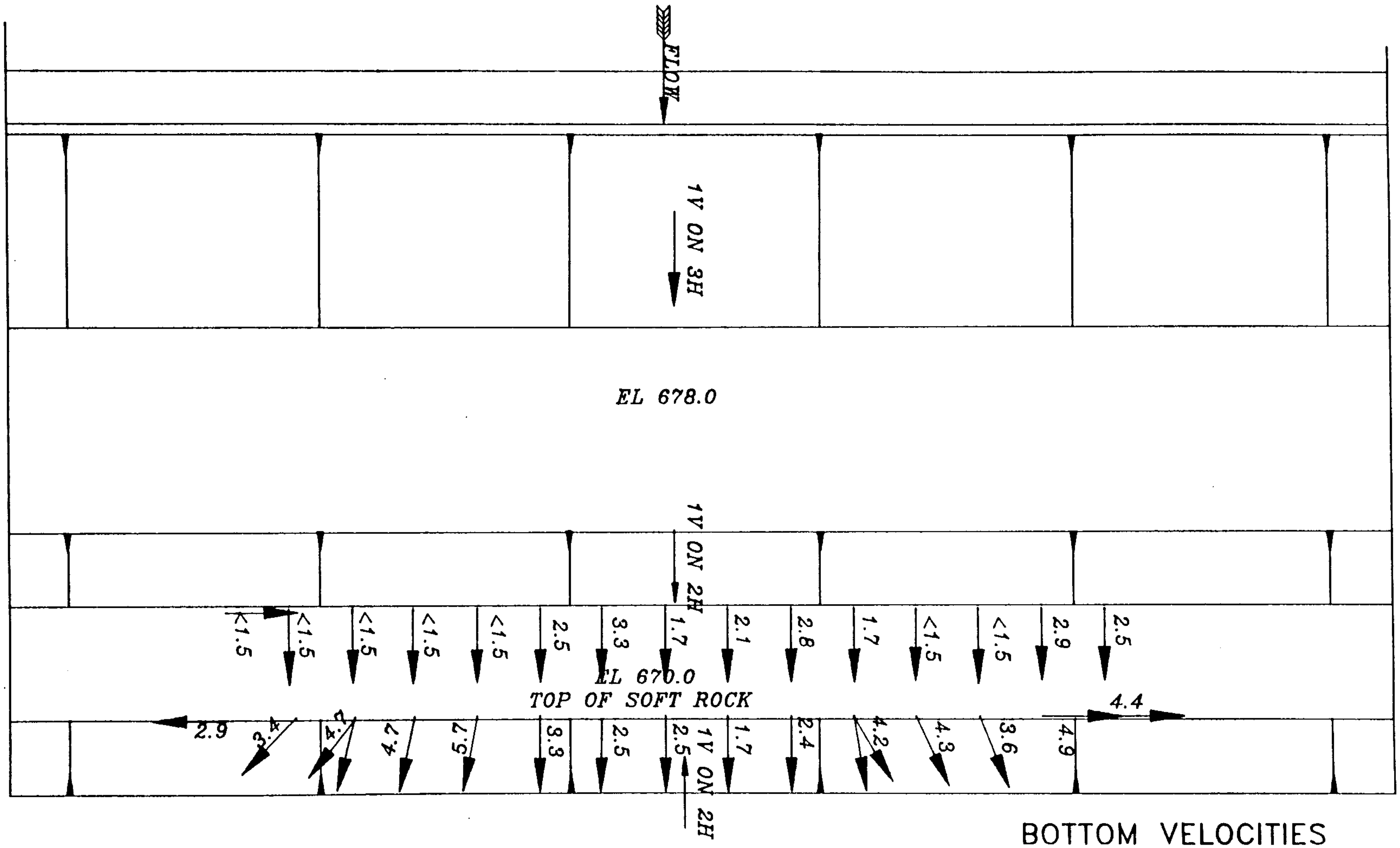

BOTTOM VELOCITIES
OPTION D RIPRAP
G_M = 4 FT
Q = 8,700 CFS
POOL EL 723.7, TW EL 715.0
FLOW
1V ON 3H
EL 678.0
1V ON 2H
EL 672.0
TOP OF SOFT ROCK
1V ON 2H
<1.5
1.6
>1.5
Note: Crest El 704.7
Velocities measured in ft per sec


BOTTOM VELOCITIES
OPTION D RIPRAP
G_M = 10 FT
Q = 21,500 CFS
POOL EL 723.7, TW EL 710.0
FLOW
1V ON 3H
EL 678.0
1V ON 2H
EL 670.0
TOP OF SOFT ROCK
1V ON 2H
Note: Crest El 704.7
Velocities measured in ft per sec



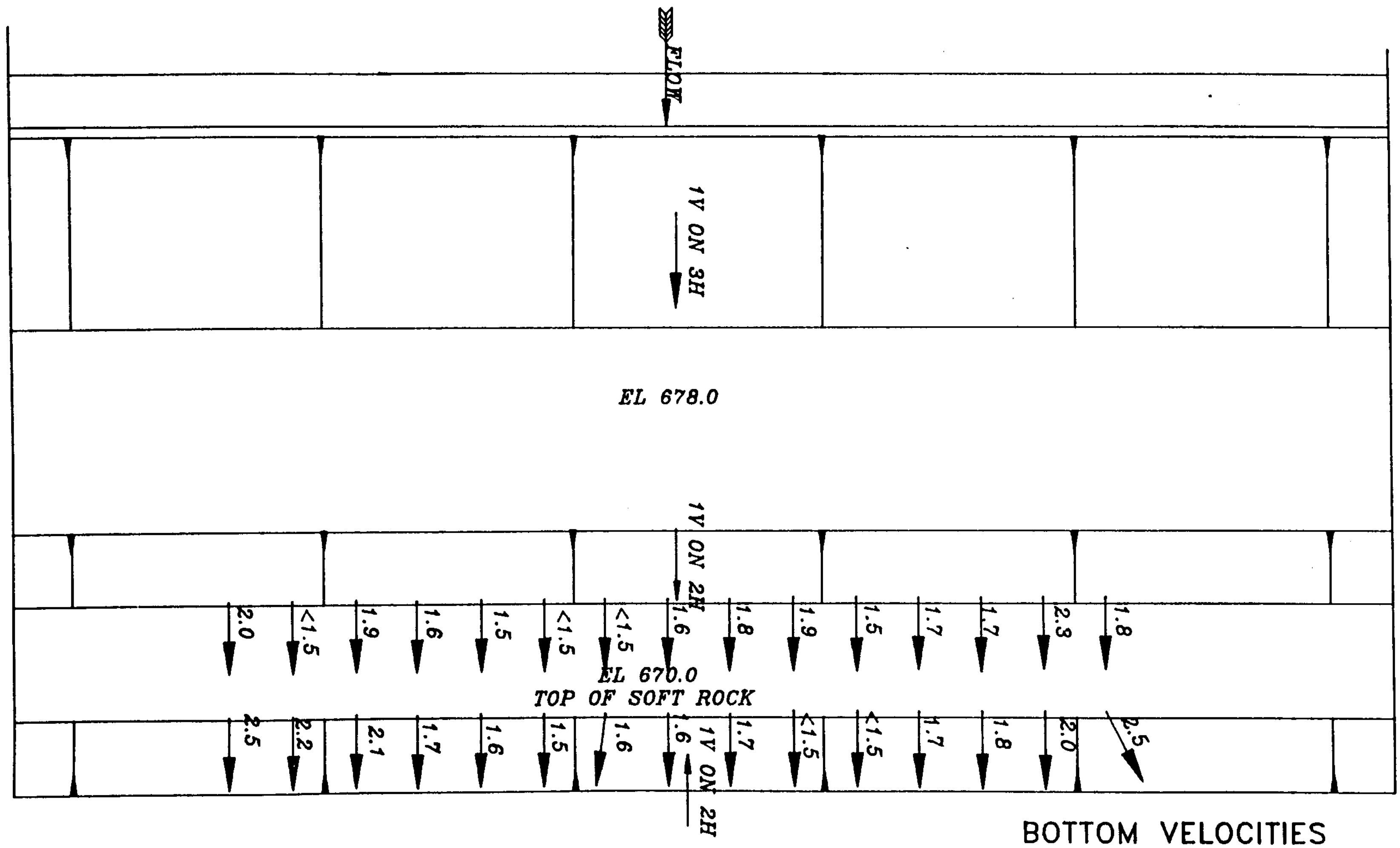
Note: *Crest El 704.7*
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION D RIPRAP
ALL THREE GATES OPEN 4.0 FT
Q = 25,000 CFS
POOL EL 723.7, TW EL 715.0



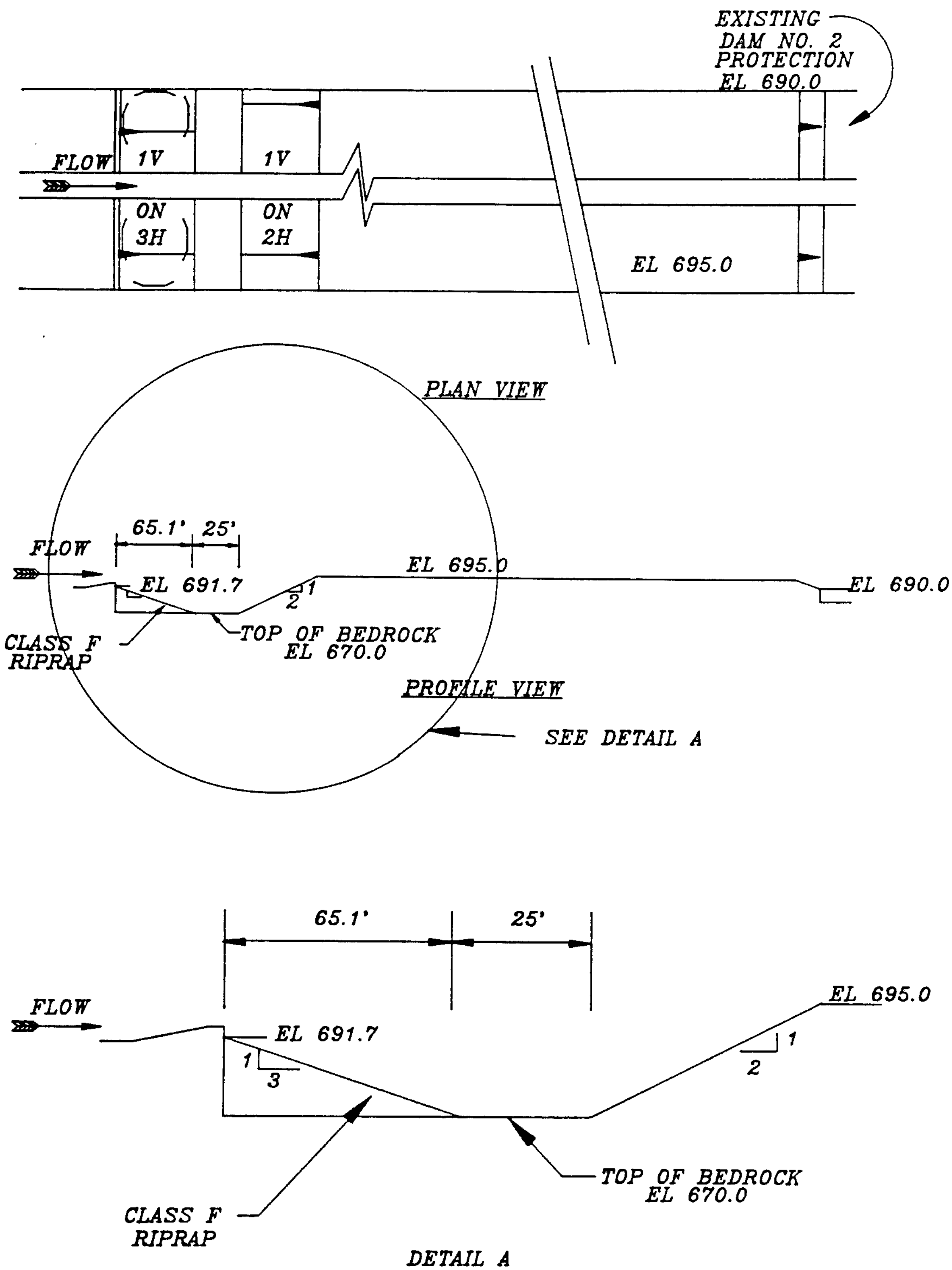
Note: *Crest El 704.7*
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION D RIPRAP
G_M = FULL OPEN
Q = 27,500 CFS
POOL EL 723.7, TW EL 711.0

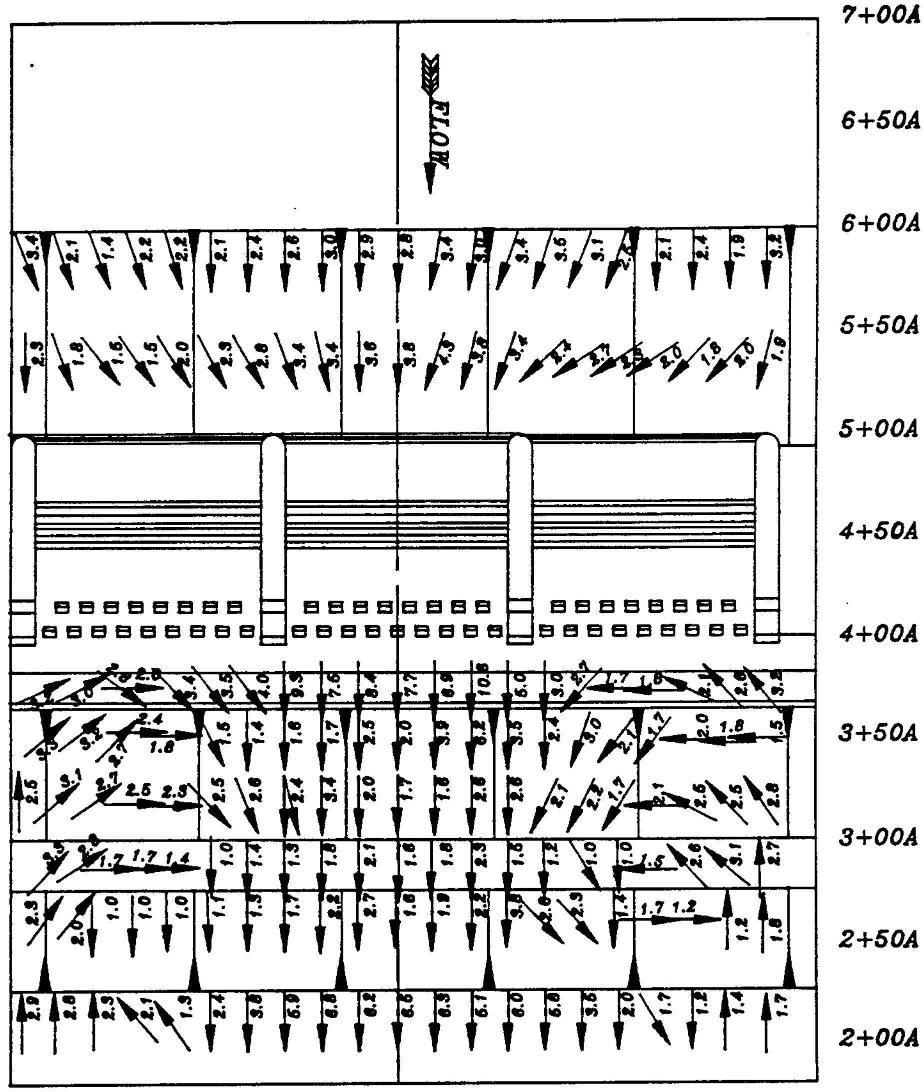


Note: *Crest El 704.7*
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION D RIPRAP
ALL THREE GATES OPEN FULL
Q = 93,000 CFS
POOL EL 723.7, TW EL 721.0

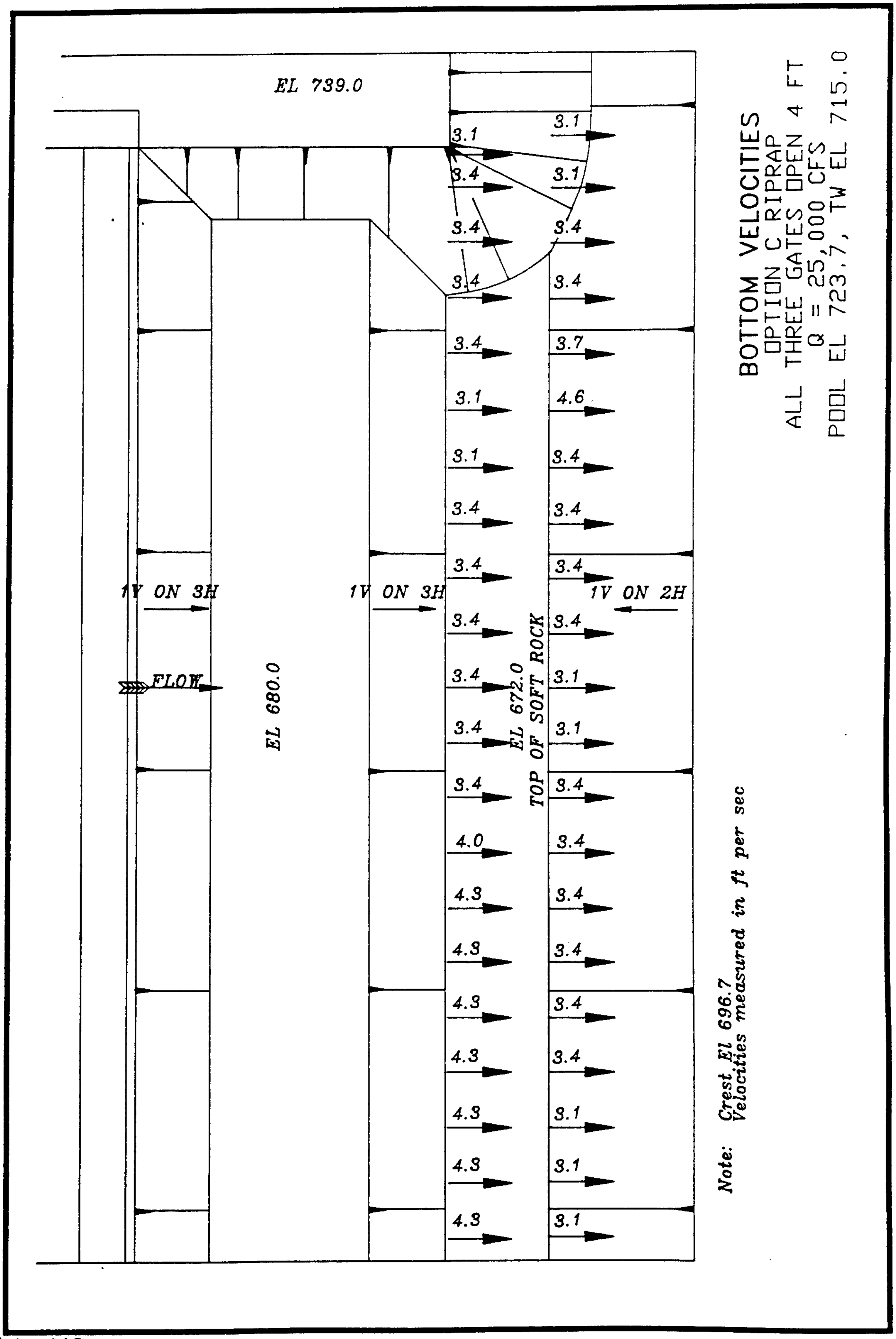


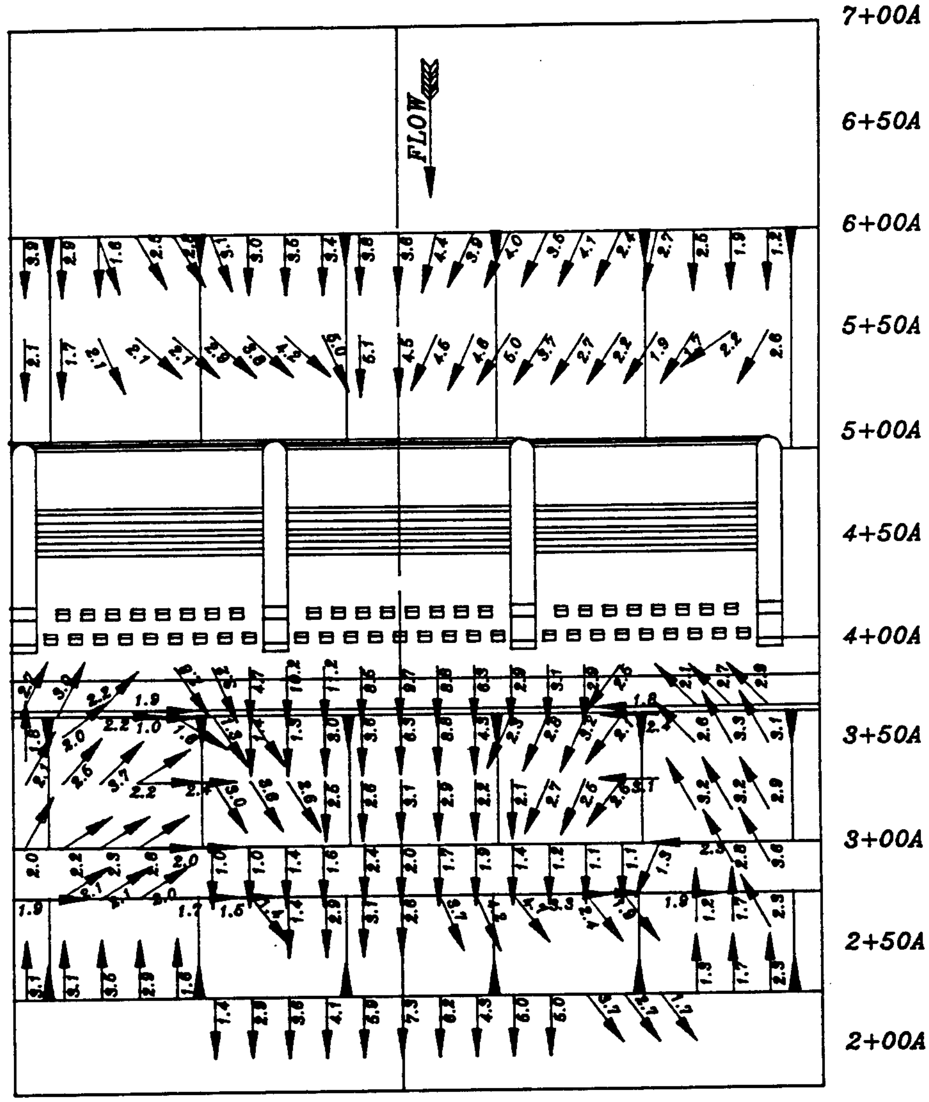
OPTION E
RIPRAP DETAIL



Note: *Crest El 704.7*
Velocities measured in ft per sec

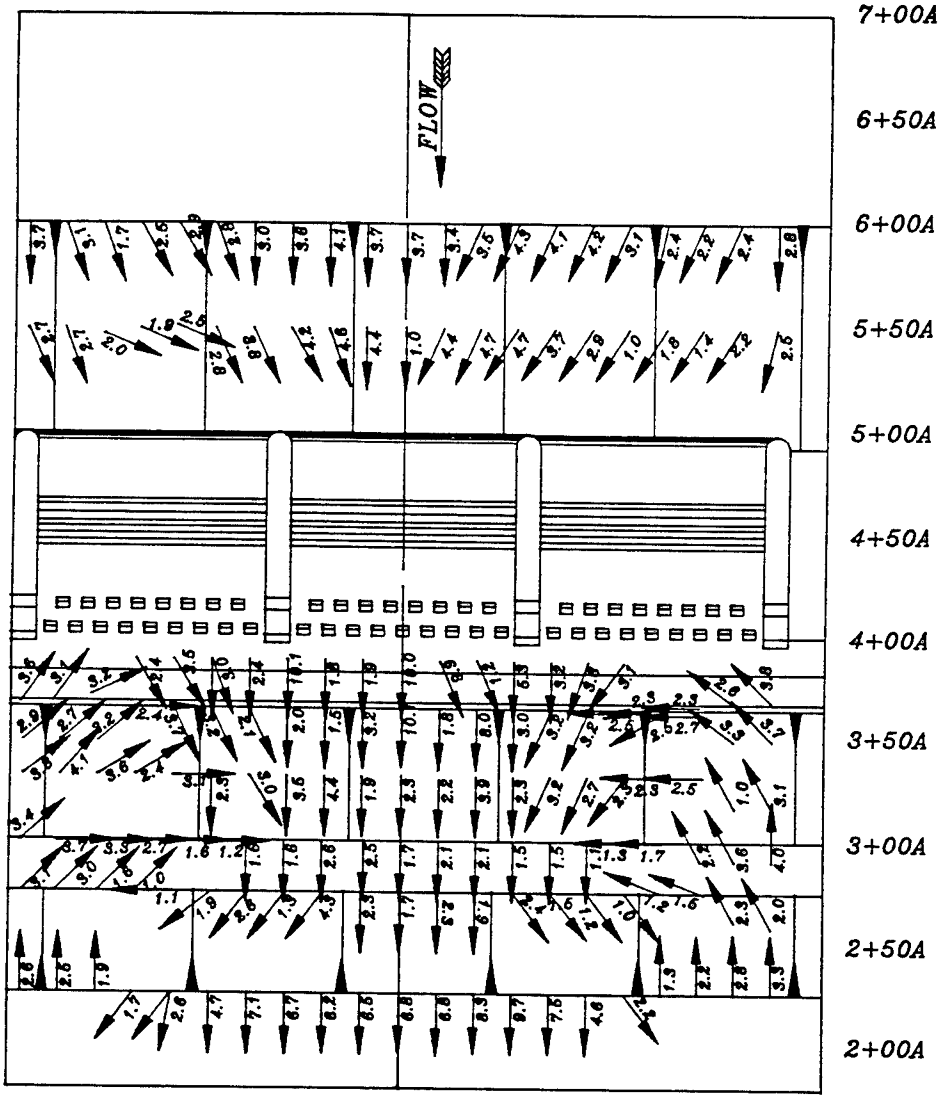
BOTTOM VELOCITIES
OPTION E RIPRAP
G_M = 10 FT
Q = 21,500 CFS
POOL EL 723.7, TW EL 710.0


BOTTOM VELOCITIES
OPTION C RIPRAP
ALL THREE GATES OPEN 4 FT
Q = 25,000 CFS
POOL EL 723.7, TW EL 715.0
EL 739.0
EL 680.0
EL 672.0
TOP OF SOFT ROCK
1V ON 3H
1V ON 3H
1V ON 2H
FLOW
Note: Crest El 696.7
Velocities measured in ft per sec



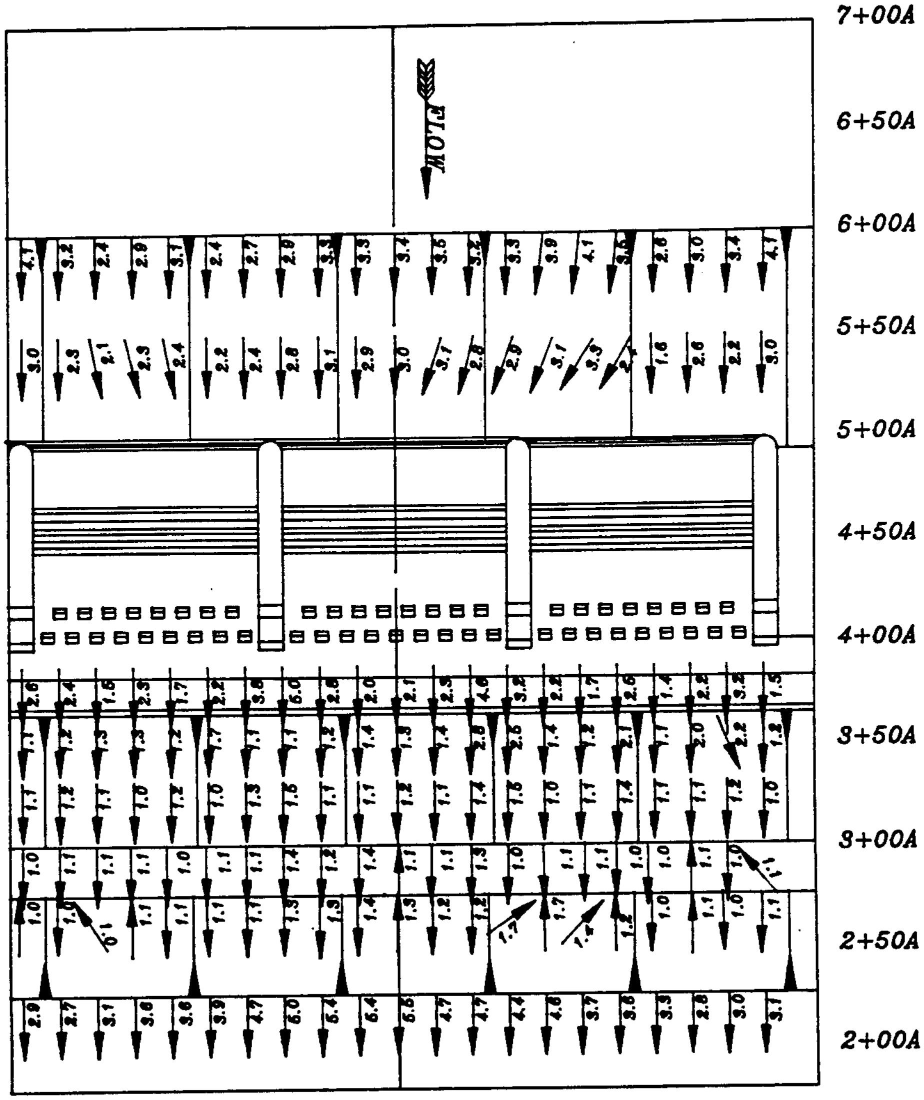
Note: Crest El 704.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_M= FULL
Q = 27,000 CFS
POOL EL 723.7, TW EL 718.5



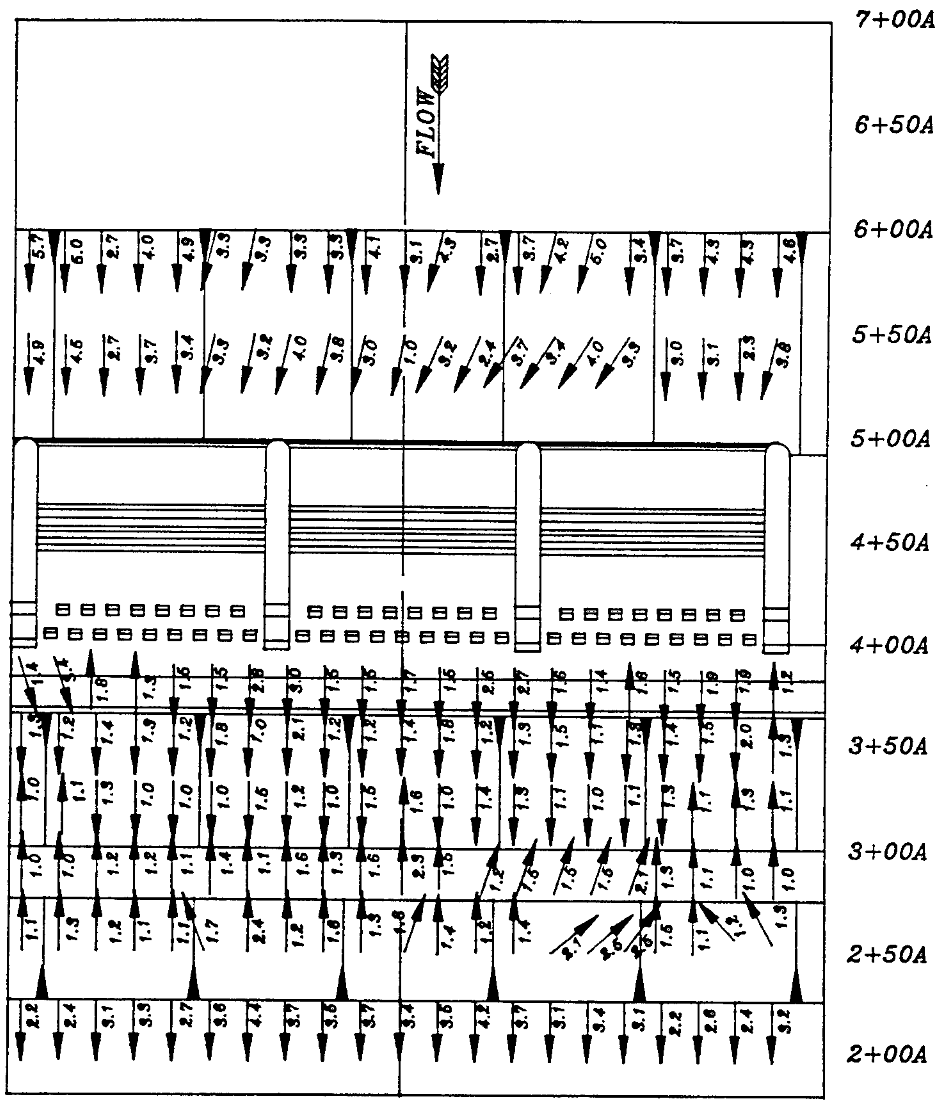
Note: *Crest El 704.7*
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_M = FULL
Q = 27,500 CFS
POOL EL 723.7, TW EL 711.0



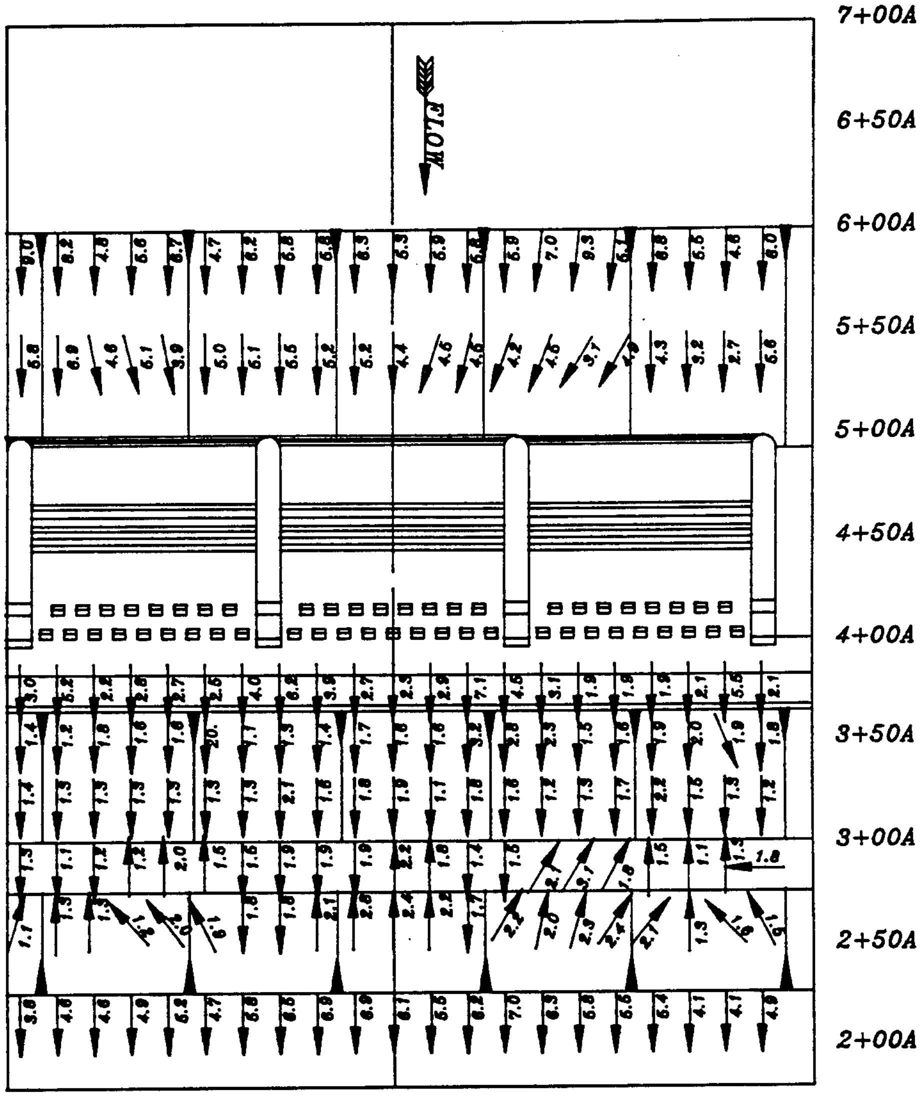
Note: Crest El 704.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
$G_L = 4$ FT, $G_M = 6$ FT, $G_R = 4$ FT
Q = 28,500 CFS
POOL EL 723.7, TW EL 714.5



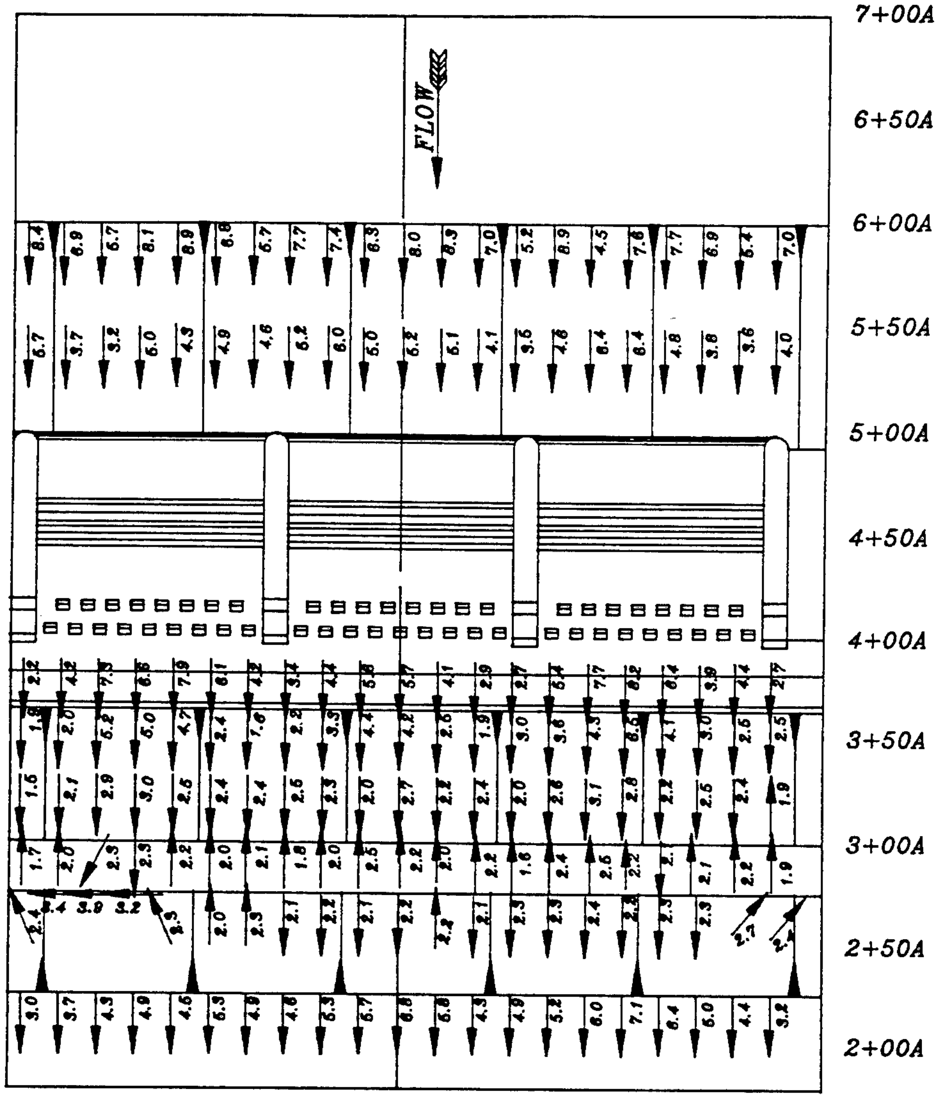
Note: *Crest El 704.7*
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
ALL THREE GATES OPEN 8 FT
Q = 33,000 CFS
POOL EL 723.7, TW EL 720.0



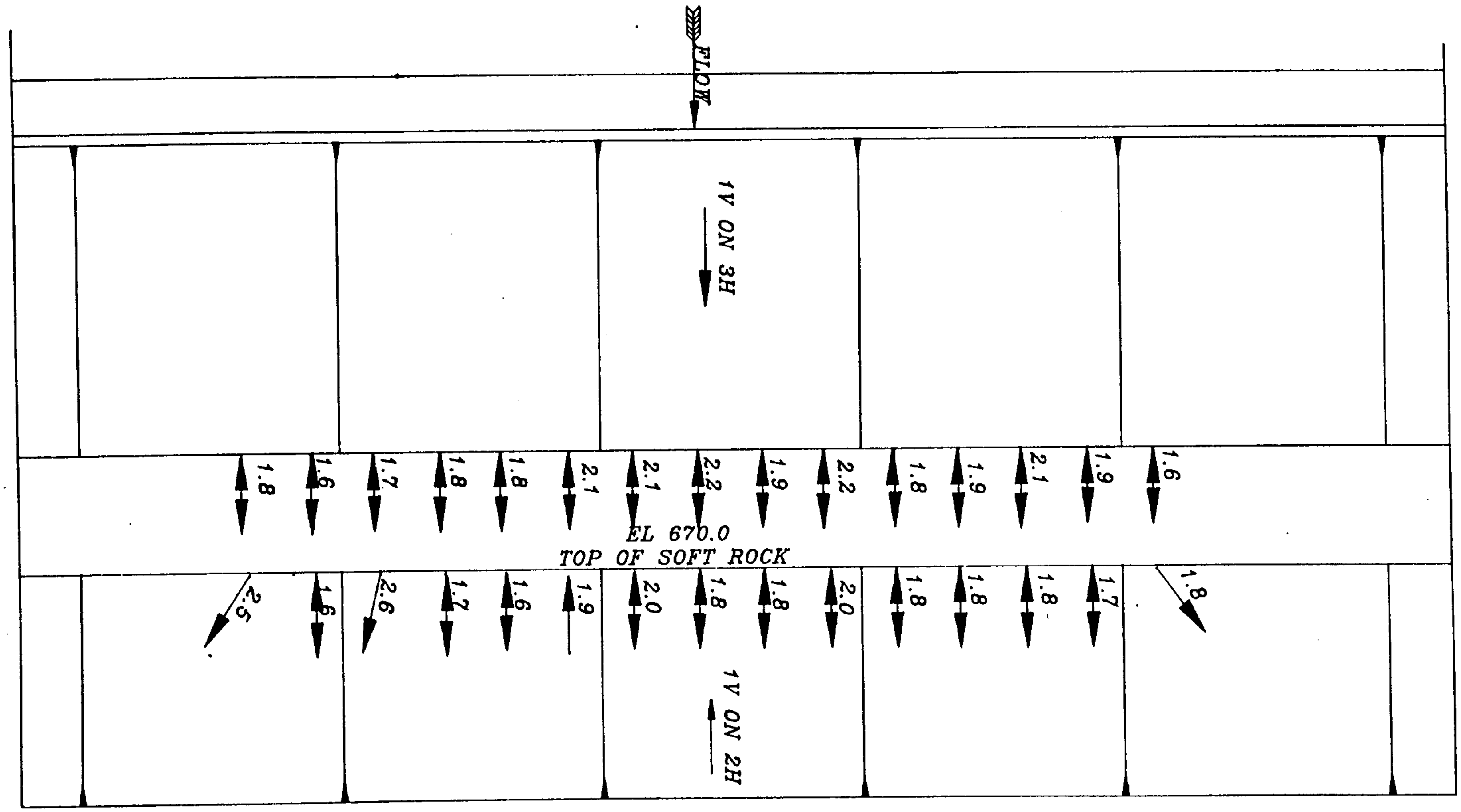
Note: *Crest El 704.7*
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_L = 8 FT, G_M = 10 FT, G_R = 8 FT
Q = 48,000 CFS
POOL EL 723.7, TW EL 717.0



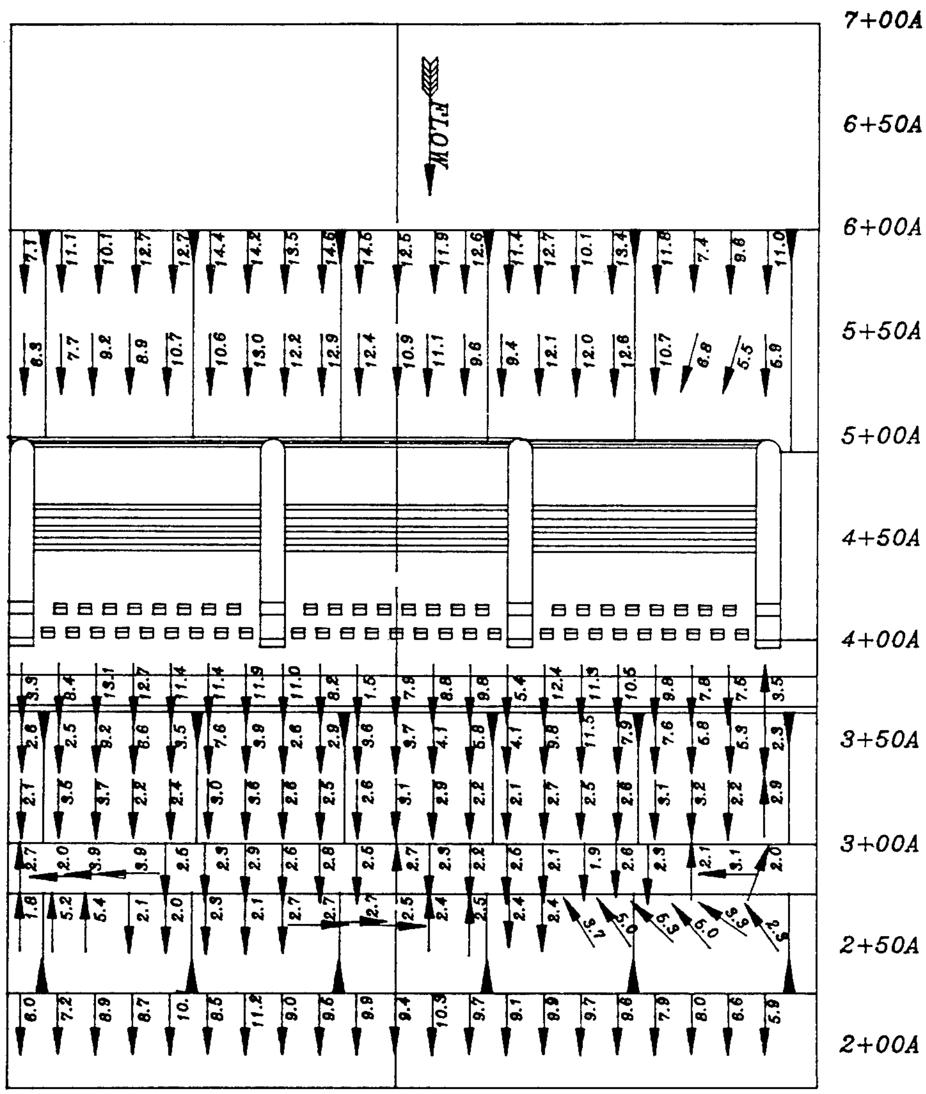
Note: Crest El 704.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
ALL THREE GATES OPEN FULL
Q = 75,000 CFS
POOL EL 721.1, TW EL 720.2



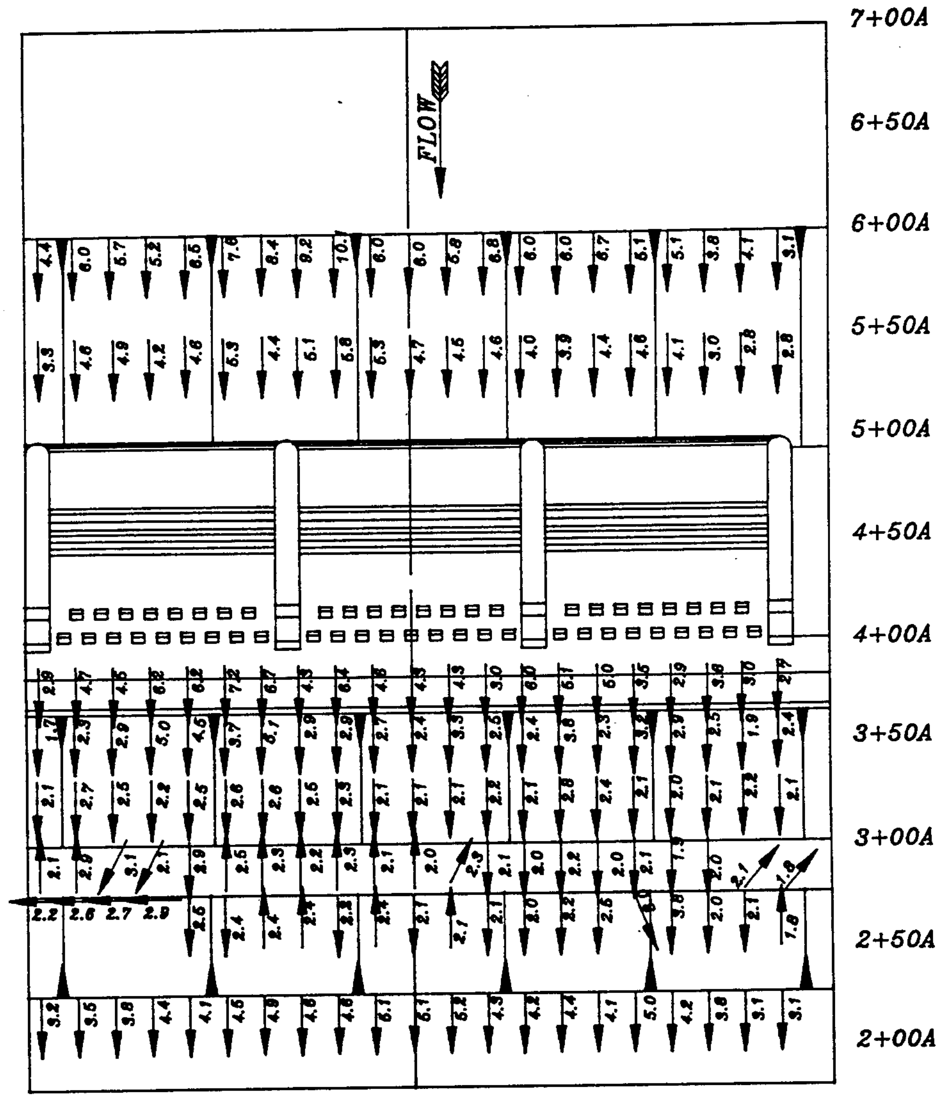
CREST EL 704.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
THREE GATES OPEN FULL
Q = 93,000 CFS
POOL EL 723.7, TW EL 721.0



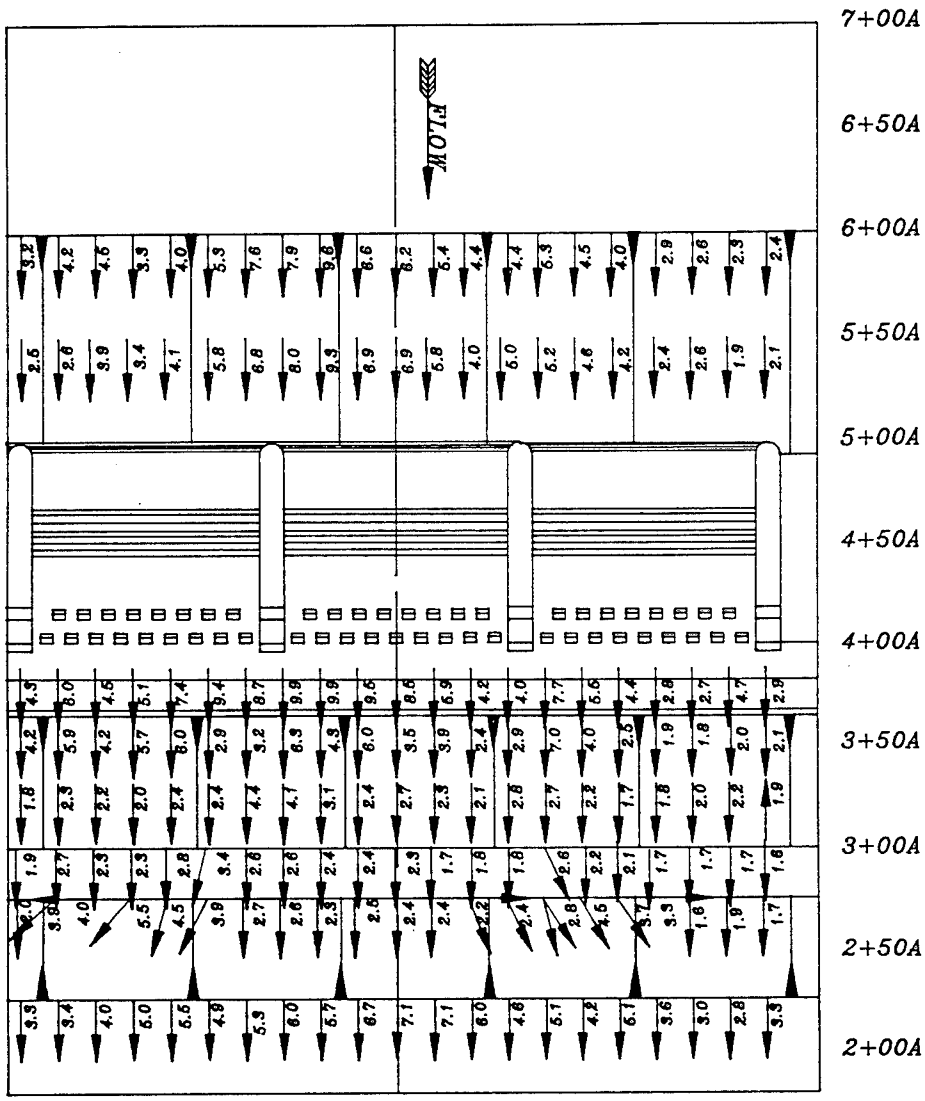
Note: *Crest El 704.7*
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
ALL THREE GATES OPEN FULL
Q = 100,000 CFS
POOL EL 723.7, TW EL 720.2



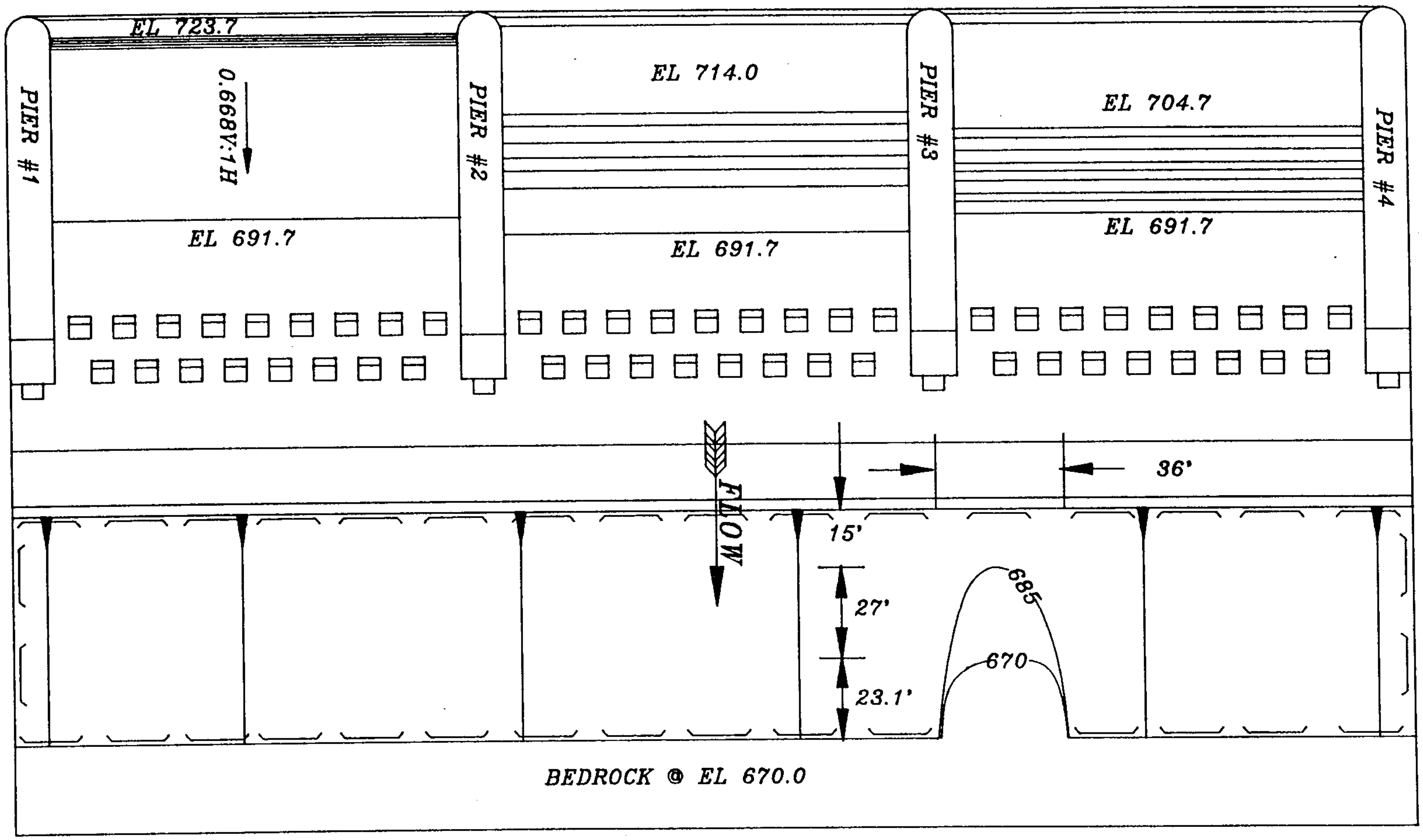
Note: *Crest El 704.7*
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
ALL THREE GATES OPEN FULL
Q = 111,000 CFS
POOL EL 729.0, TW EL 728.8



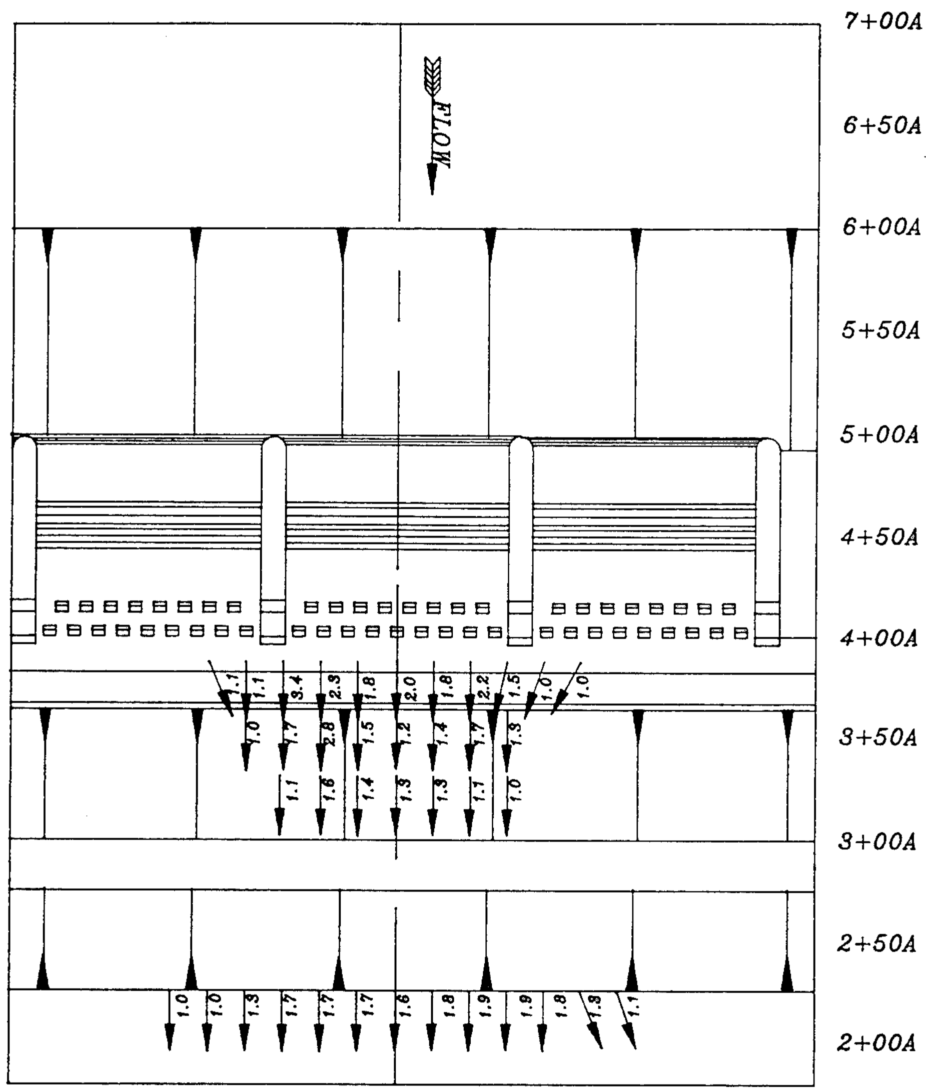
Note: Crest El 704.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
ALL THREE GATES OPEN FULL
Q = 137,000 CFS
POOL EL 737.8, TW EL 737.0



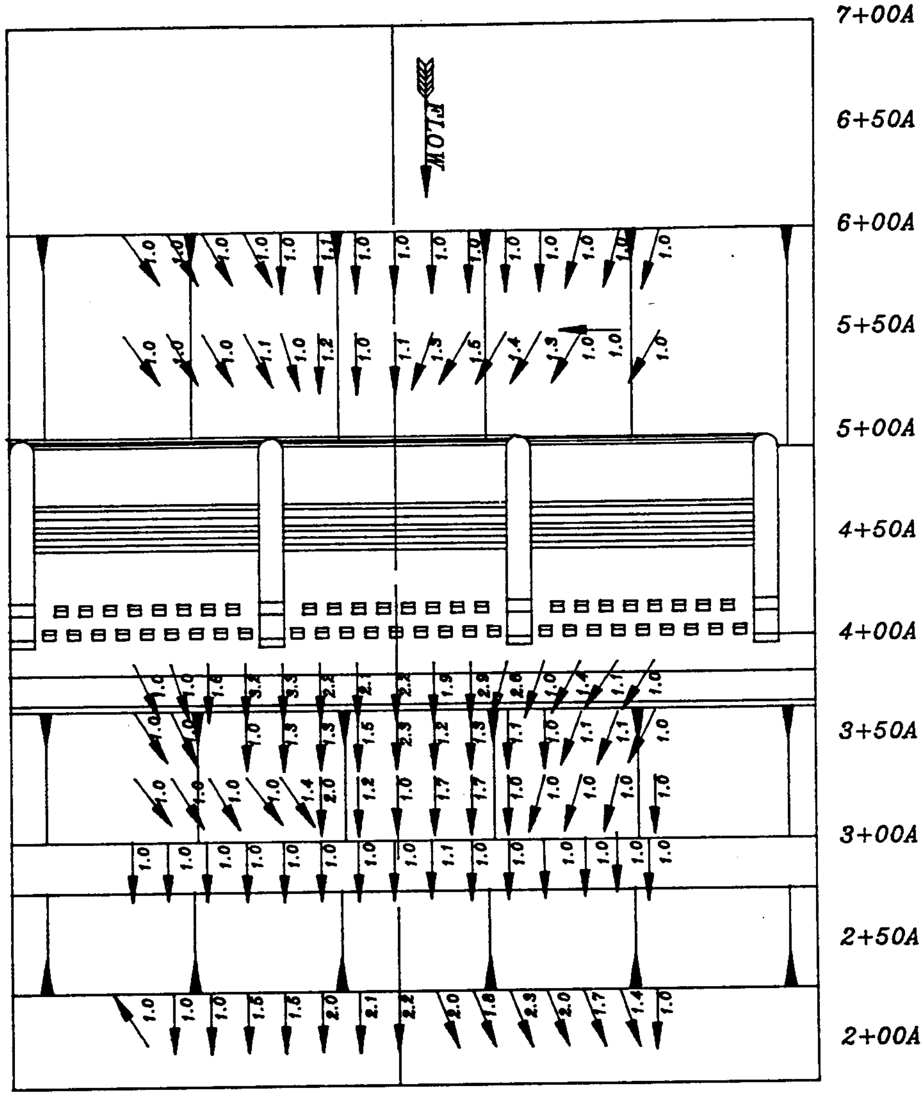
Note: $t = 48$ hr

PLAN VIEW OF SCOUR
G_L = FULL, G_{wq} = FULL
Q = 64,000 CFS
HW EL 731.8, TW EL 728.8



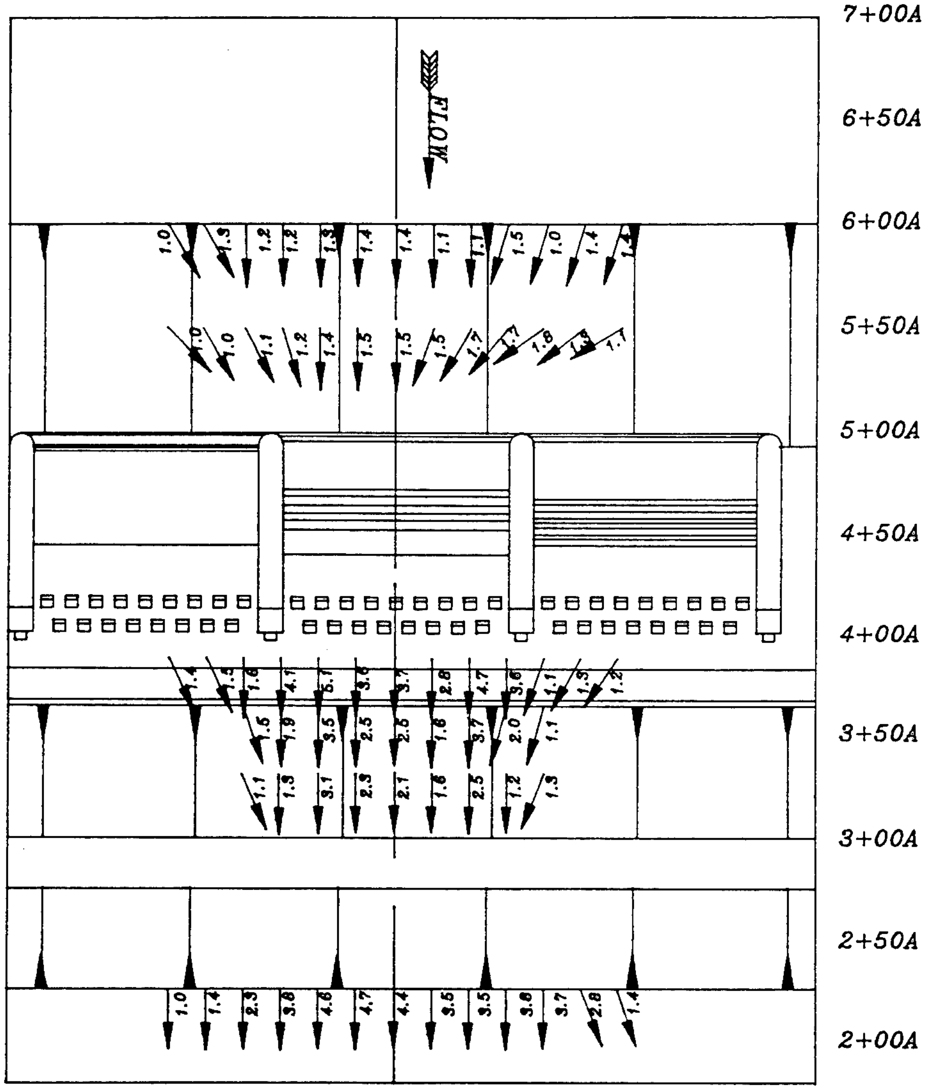
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_{wq} = 4 FT
Q = 6,800 CFS
POOL EL 723.7, TW EL 714.0



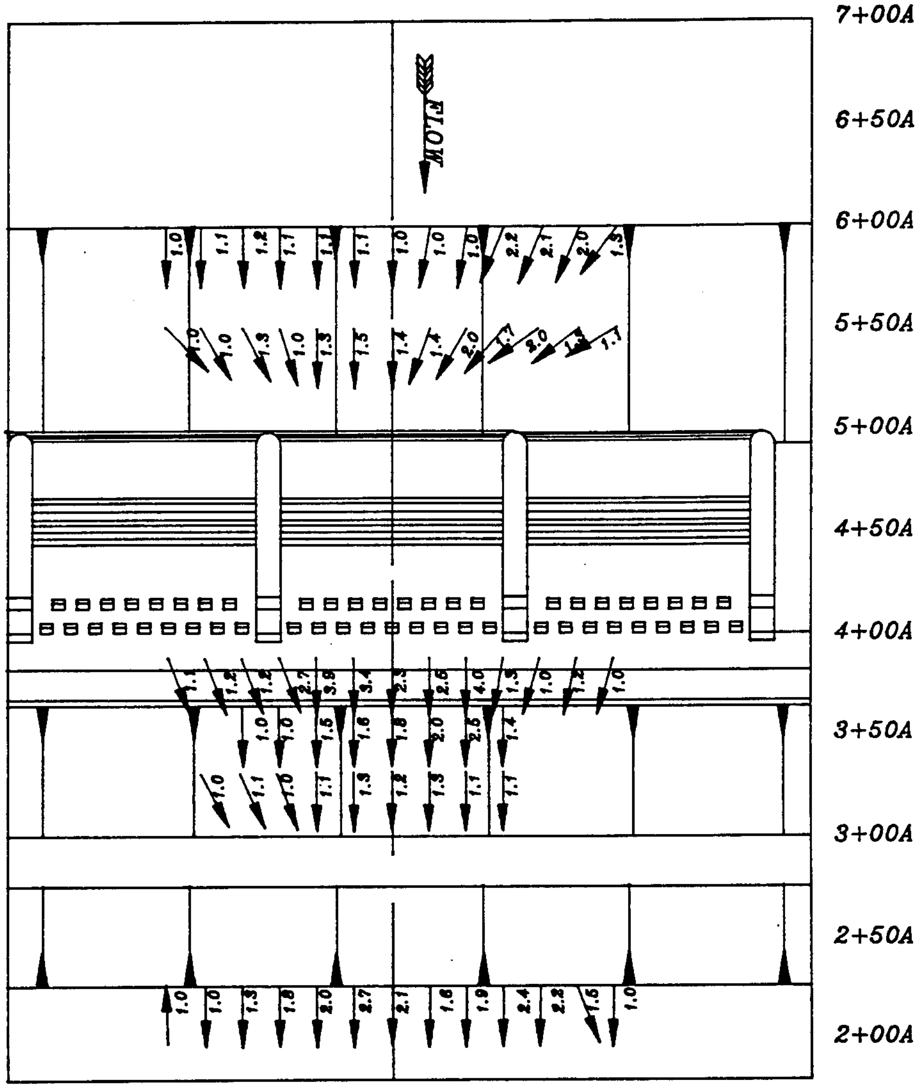
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_{wq} = 4.0 FT
Q = 7,000 CFS
POOL EL 723.7, TW EL 710.5



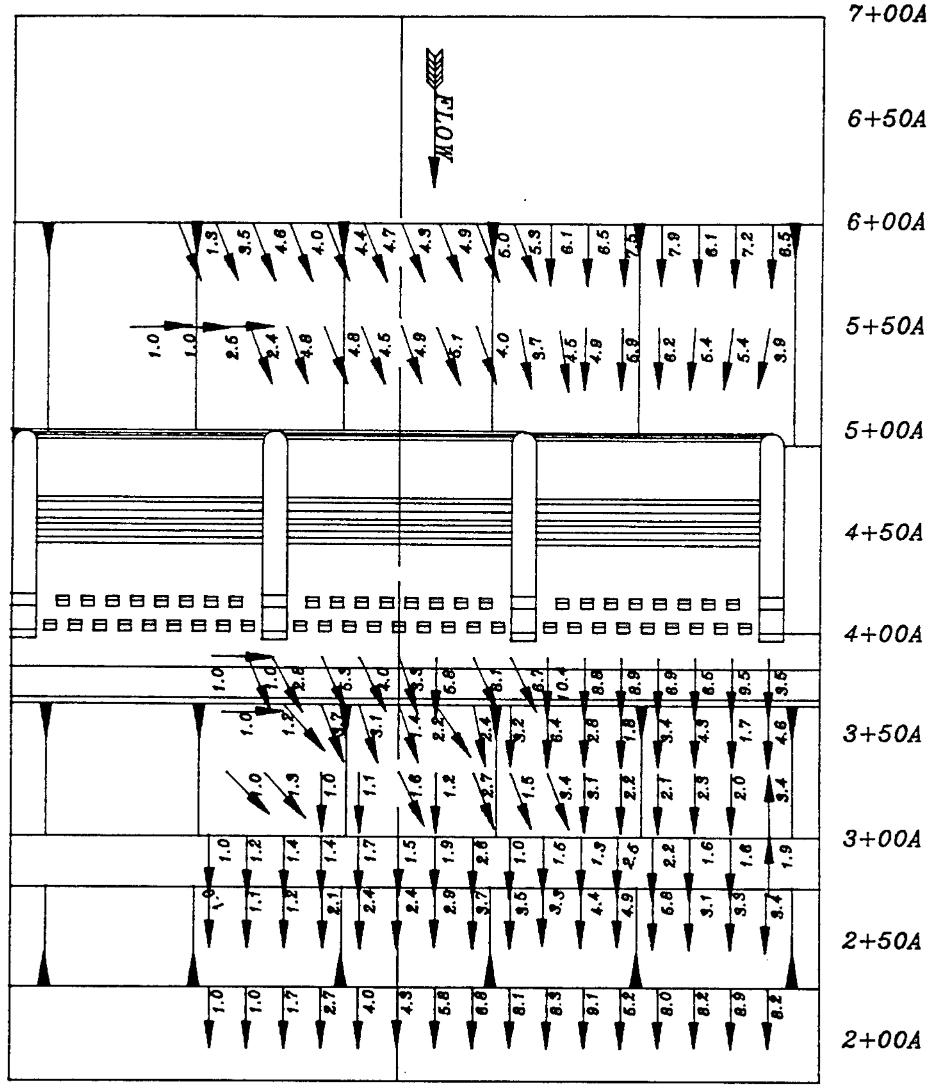
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_{wq} = FULL
Q = 10,300 CFS
POOL EL 723.7, TW EL 711.0



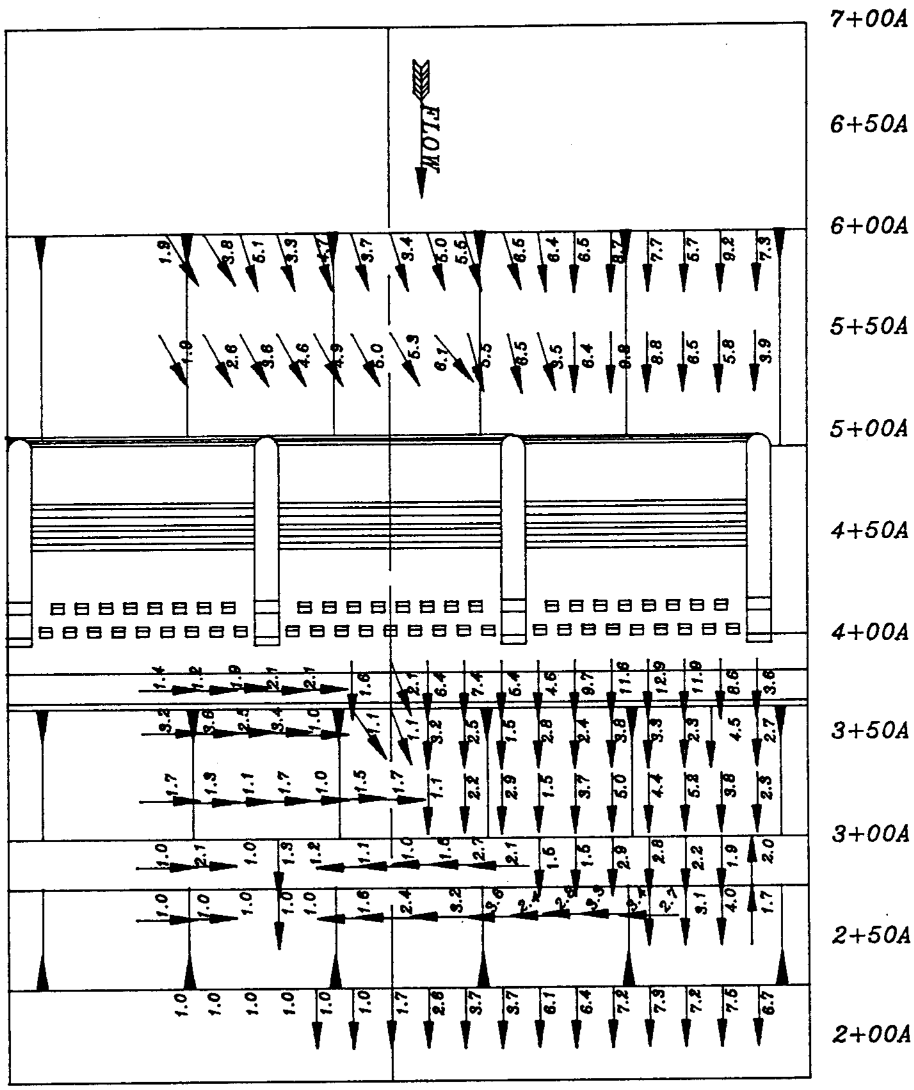
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_{wq} = FULL
Q = 10,300 CFS
POOL EL 723.7, TW EL 714.5



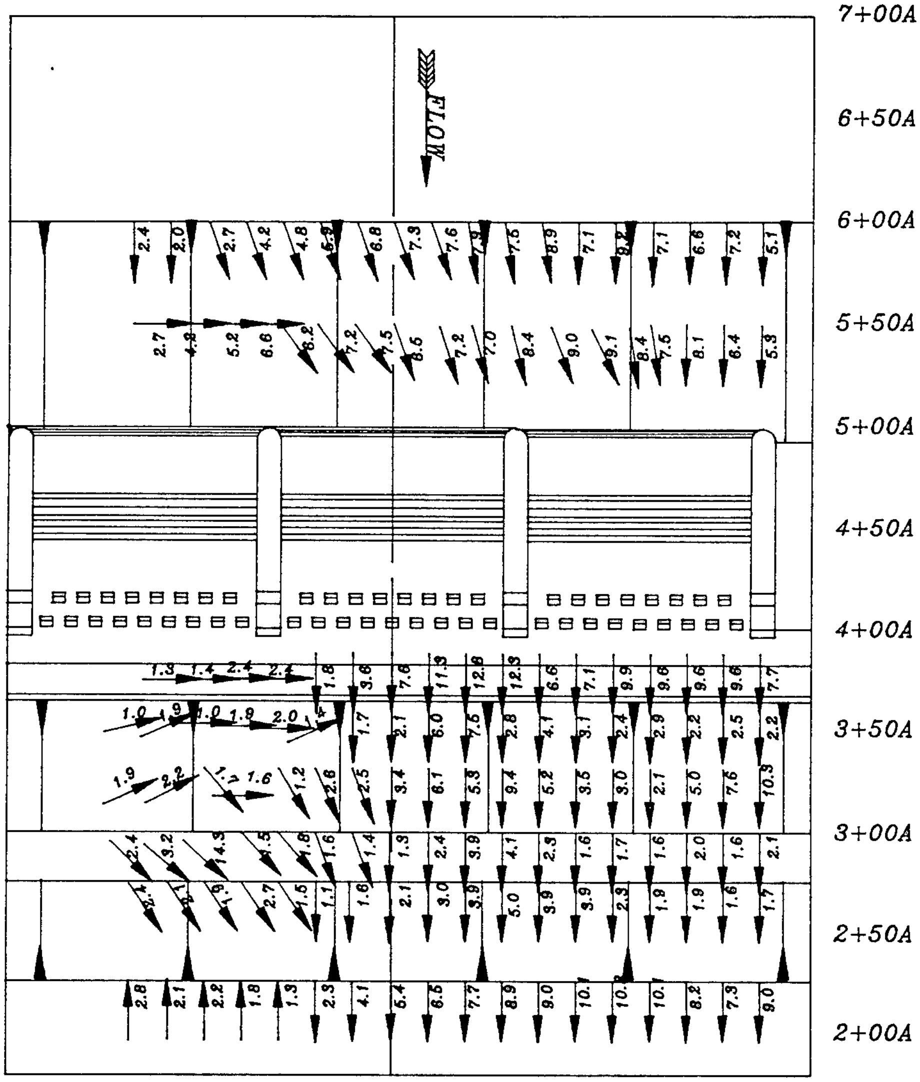
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_L = 10 FT, G_{wq} = FULL
Q = 31,000 CFS
POOL EL 723.7, TW EL 712.0



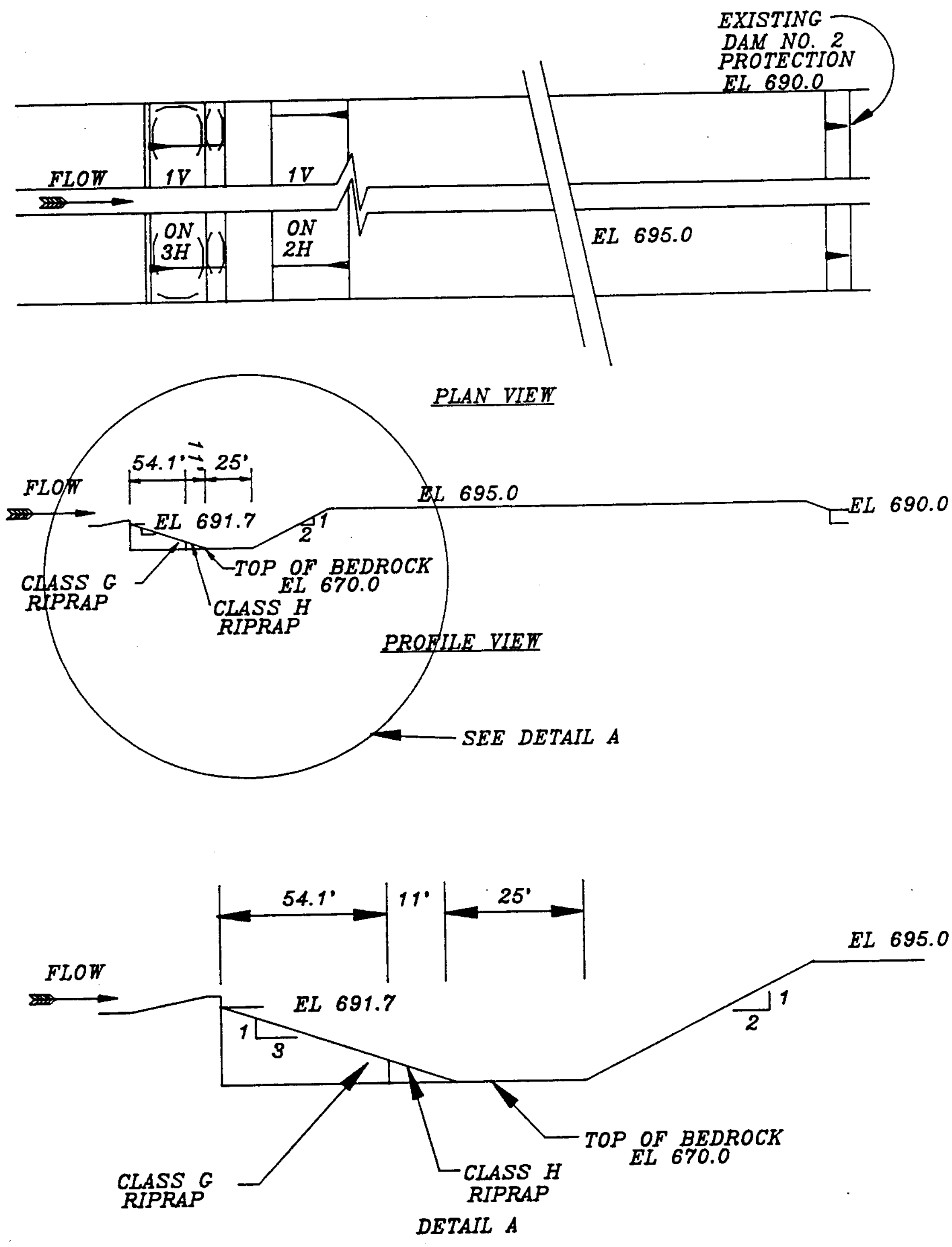
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_L = FULL, G_{wq} = FULL
Q = 36,000 CFS
POOL EL 723.7, TW EL 720.2

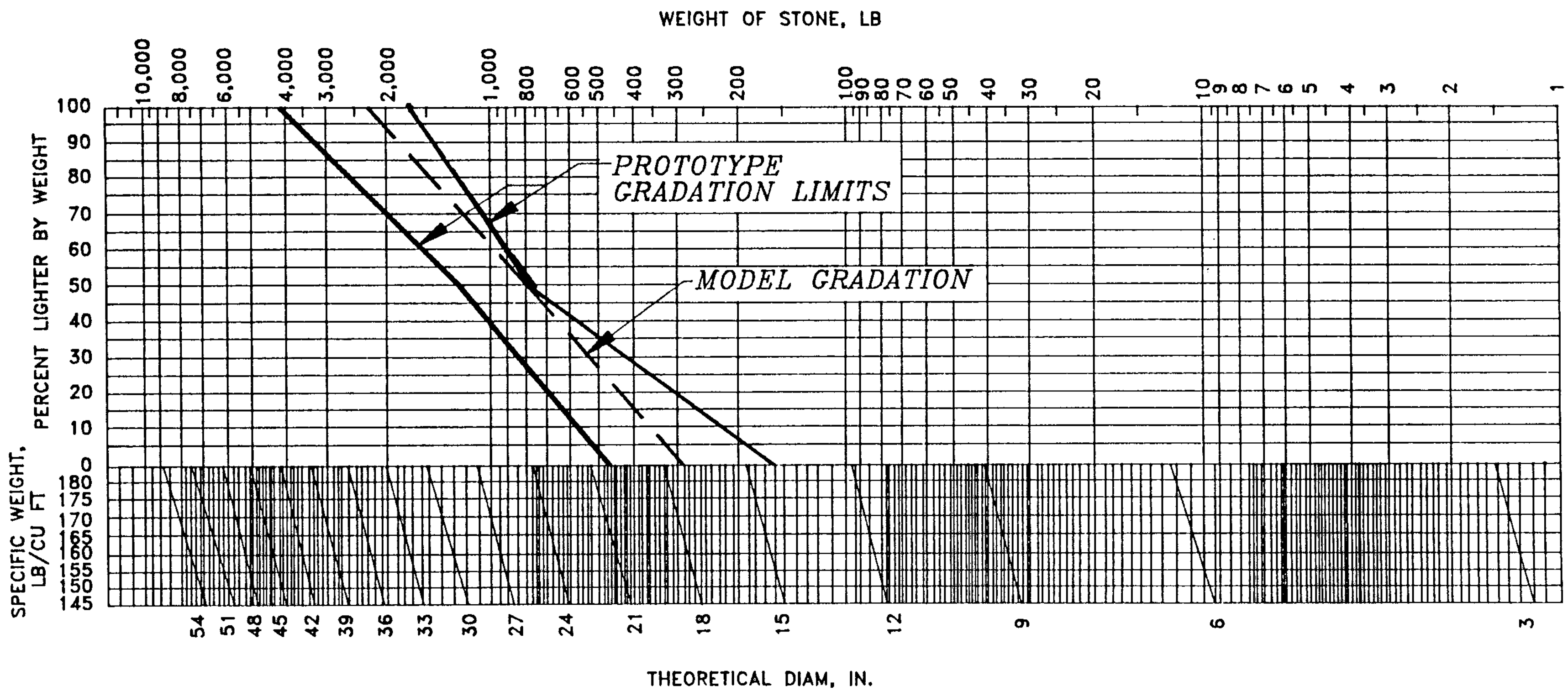


Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION E RIPRAP
G_L = FULL, G_{wq} = FULL
Q = 64,000 CFS
POOL EL 731.8, TW EL 728.8

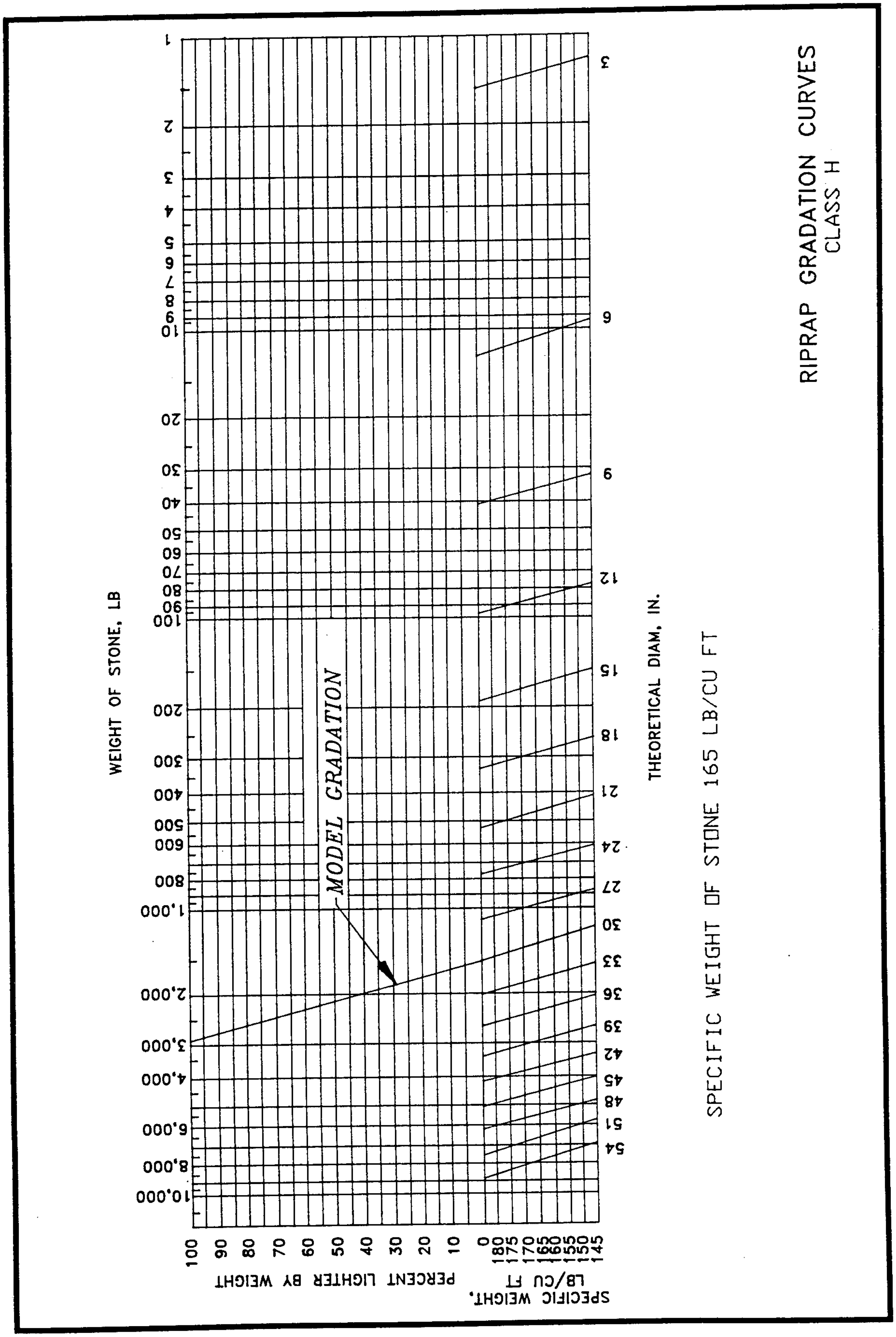


OPTION F
RIPRAP DETAIL

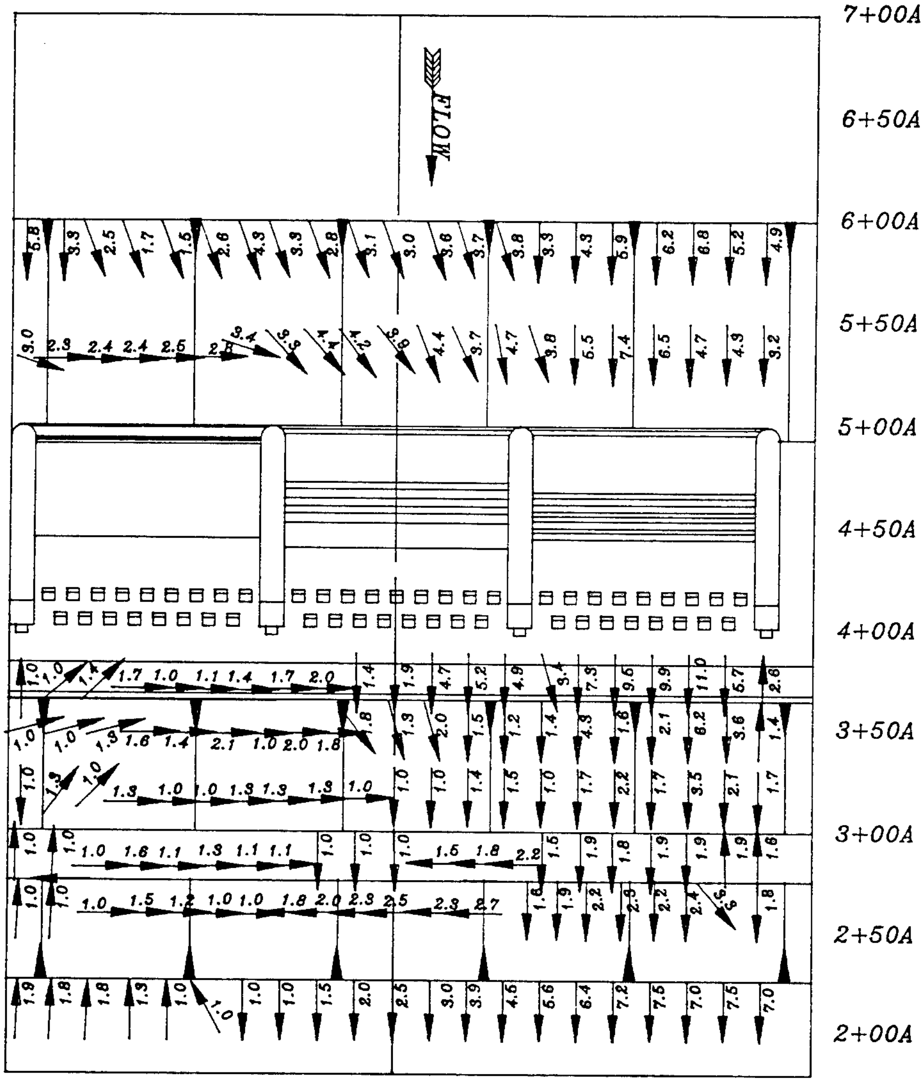


SPECIFIC WEIGHT OF STONE 165 LB/CU FT

RIPRAP GRADATION CURVES
CLASS G

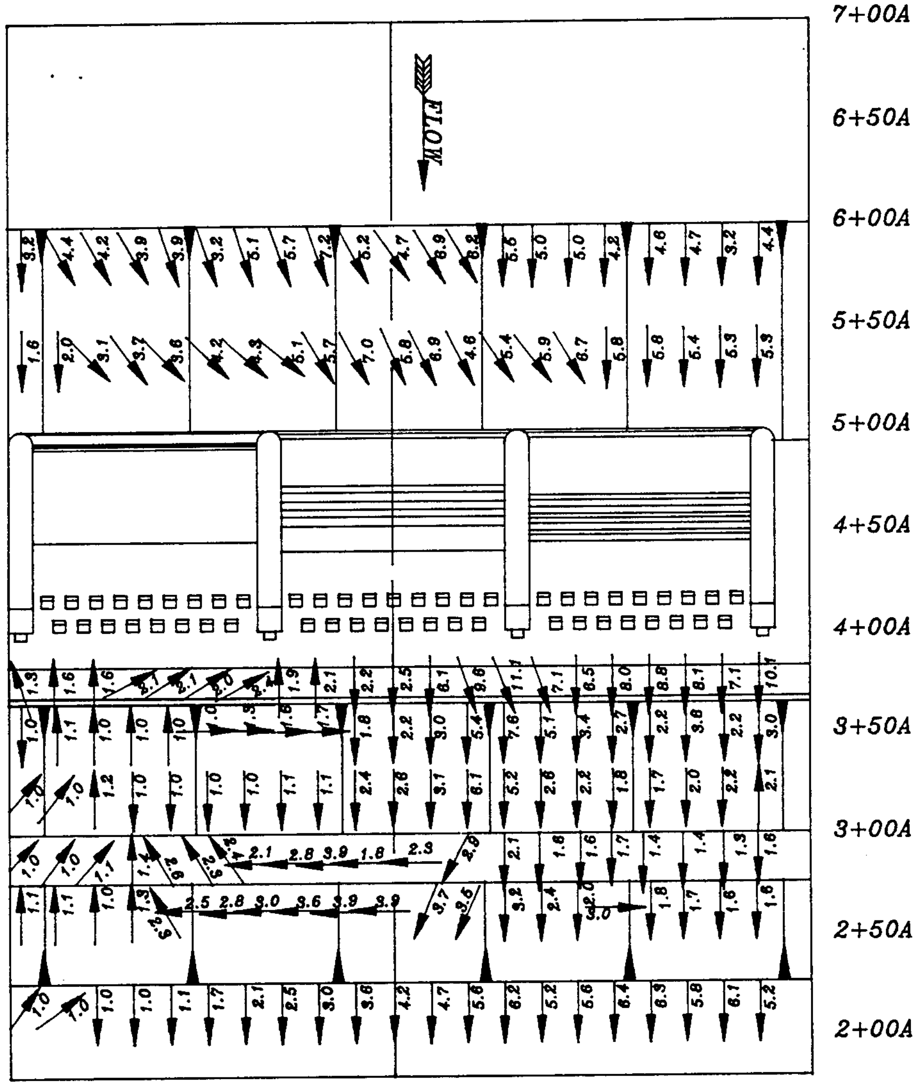


RIPRAP GRADATION CURVES
CLASS H
MODEL GRADATION
WEIGHT OF STONE, LB
1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90 100 200 300 400 500 600 800 1,000 2,000 3,000 4,000 6,000 8,000 10,000
THEORETICAL DIAM., IN.
3 6 9 12 15 18 21 24 27 30 33 36 39 42 45 48 51 54
SPECIFIC WEIGHT OF STONE 165 LB/CU FT
PERCENT LIGHTER BY WEIGHT
100 90 80 70 60 50 40 30 20 10 0
SPECIFIC WEIGHT, LB/CU FT
180 175 170 165 160 155 150 145



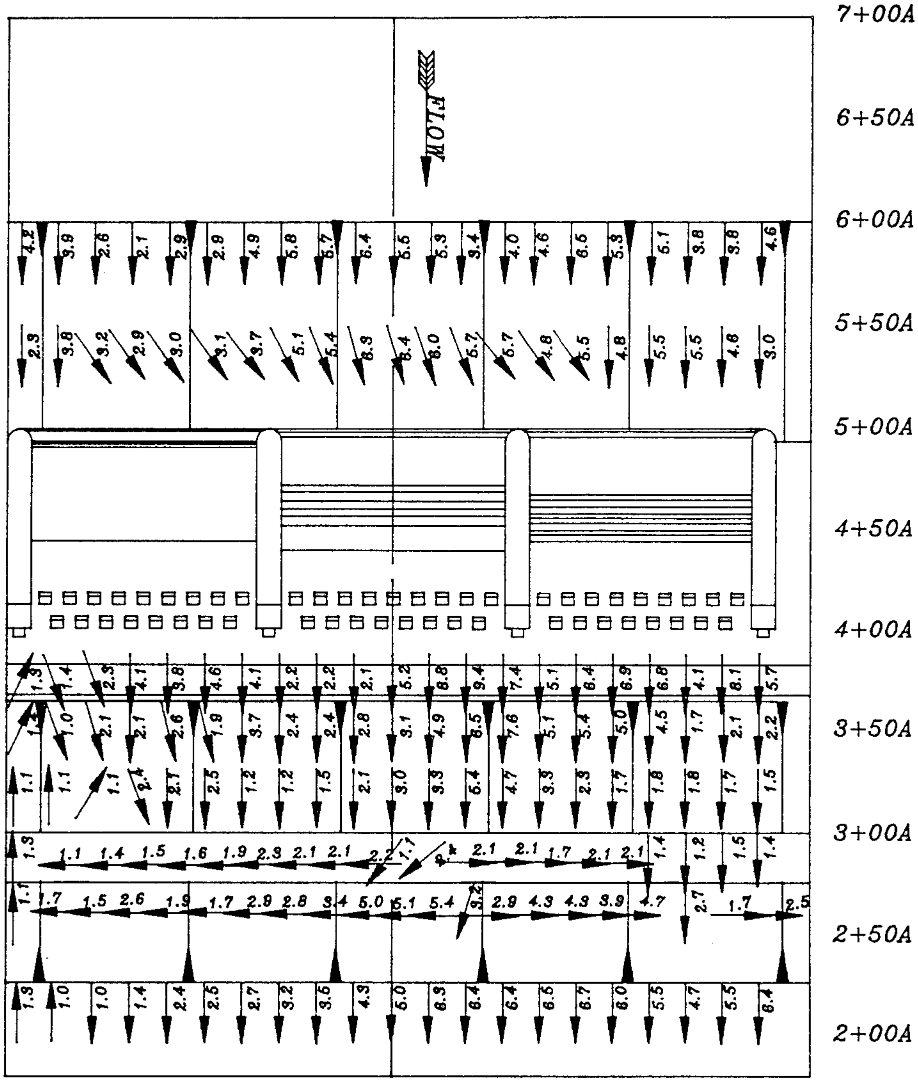
Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
TYPE F RIPRAP
G_L = FULL, G_{wq} = FULL
Q = 36,000 CFS
POOL EL 723.7, TW EL 720.2



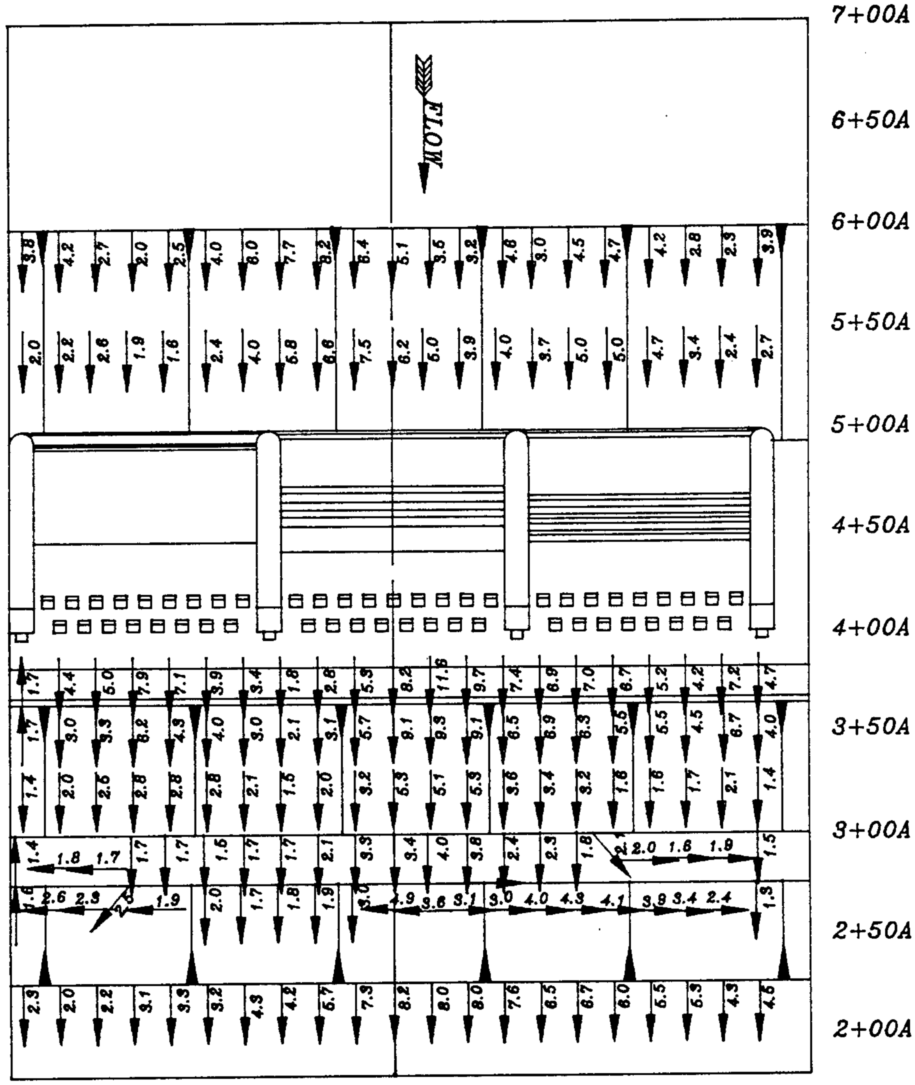
Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
TYPE F RIPRAP
G_L = FULL, G_{wq} = FULL
Q = 71,000 CFS
POOL EL 729.5, TW EL 728.8



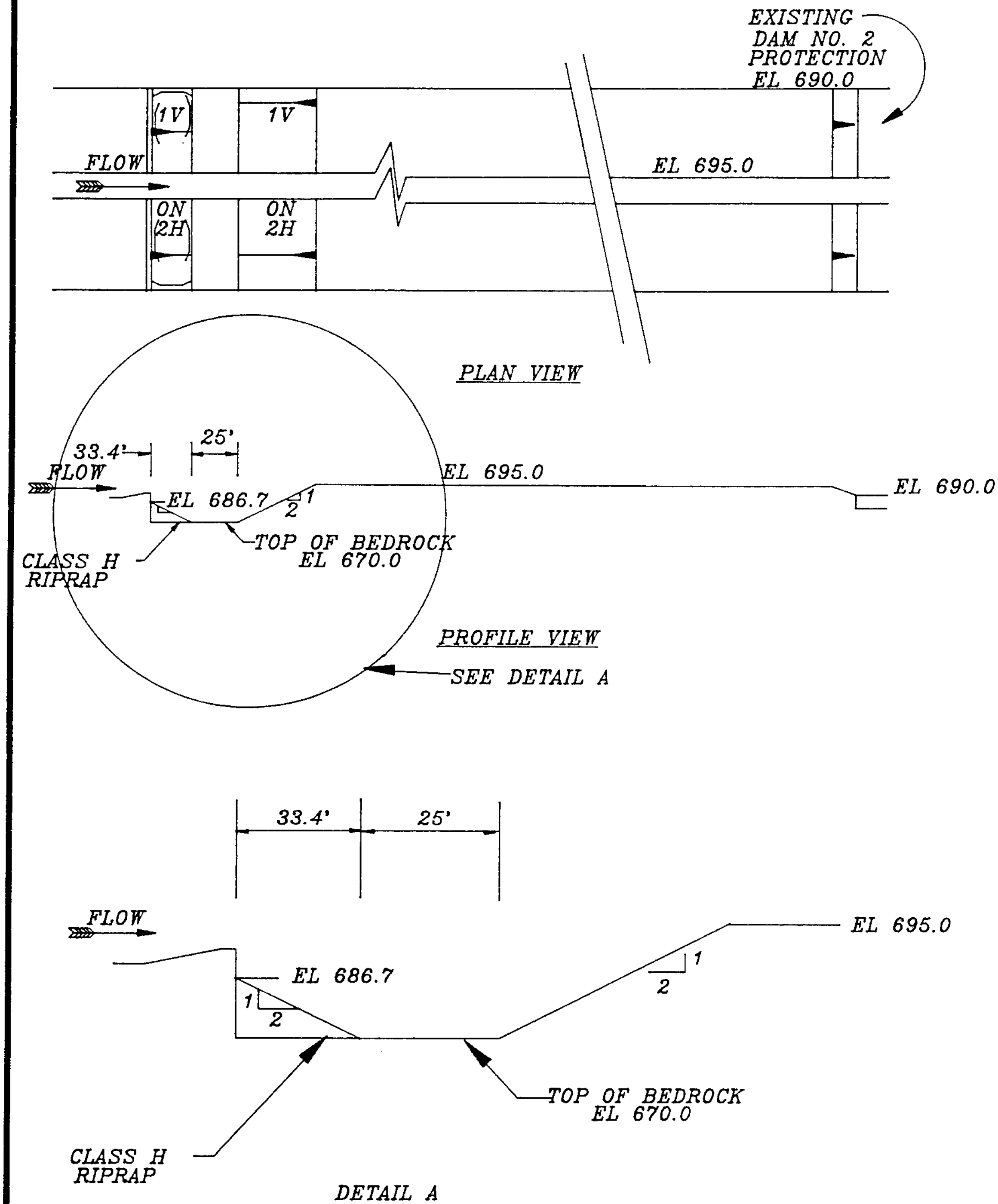
Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION F RIPRAP
G_L= FULL, G_{wq}= FULL
Q = 86,500 CFS
POOL EL 733.4, TW EL 732.7

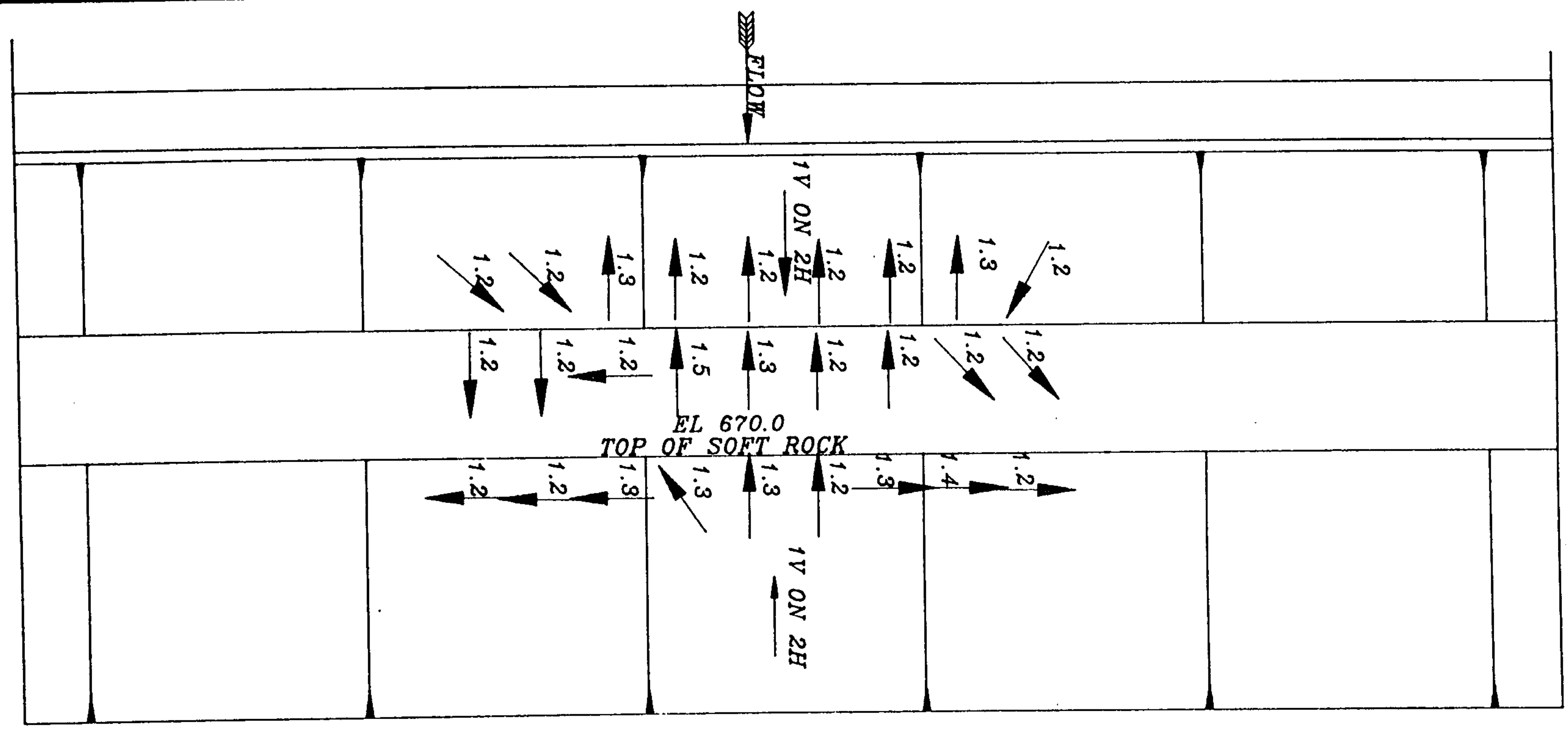


Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION F RIPRAP
G_L = FULL, G_{wq} = FULL
Q= 104,000 CFS
POOL EL 739.6, TW EL 737.0

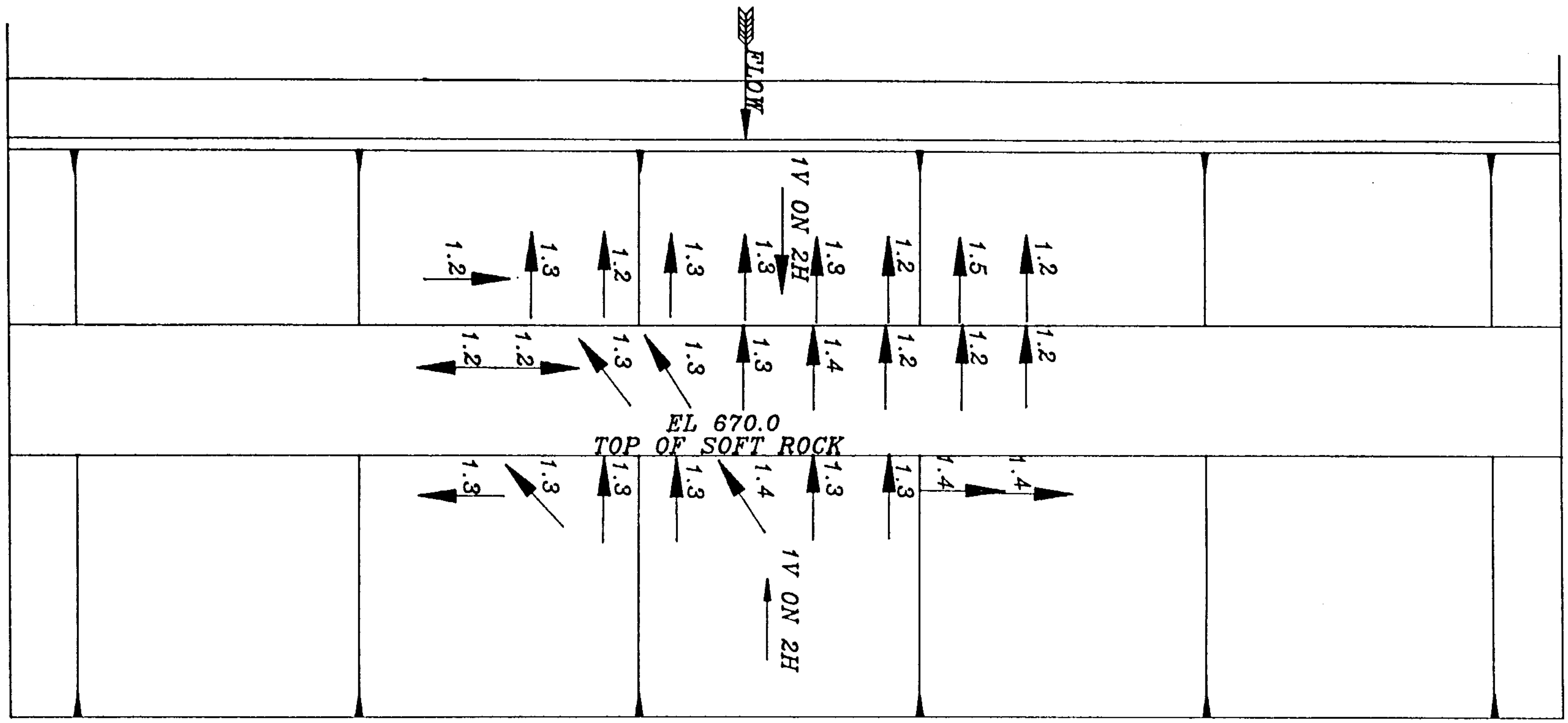


OPTION G
RIPRAP DETAIL



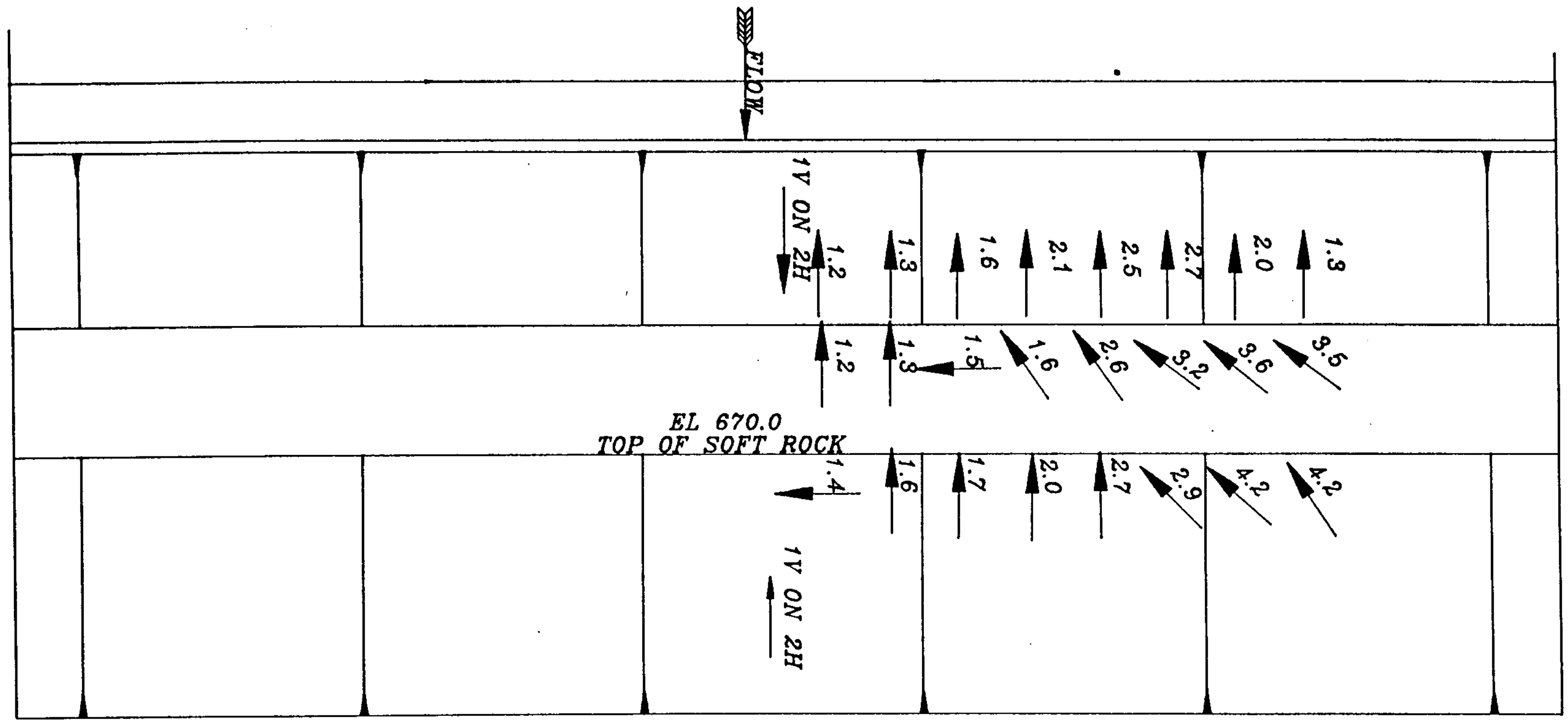
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION G RIPRAP
G_{wq} = 4 FT
Q = 7,000 CFS
POOL EL 723.7, TW EL 710.5



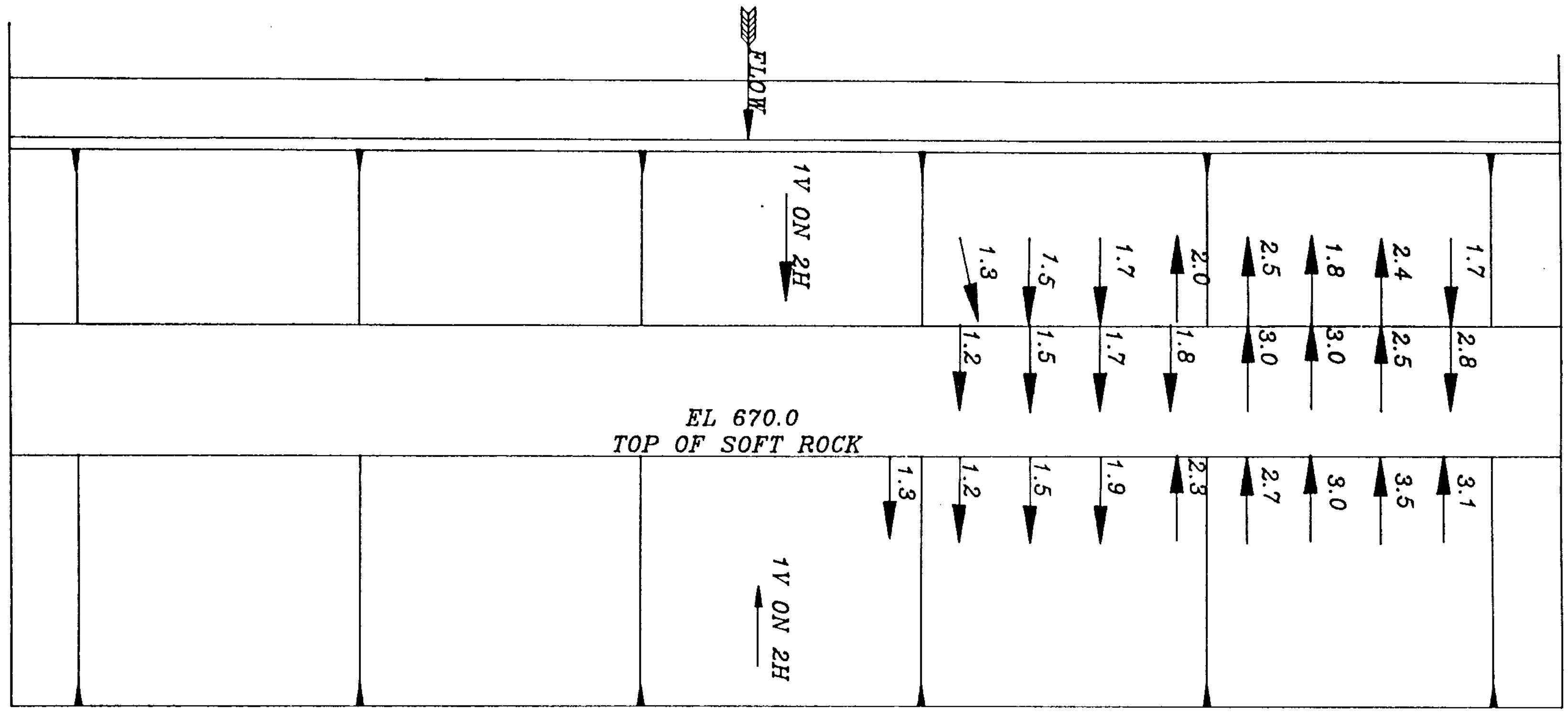
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION G RIPRAP
G_{wq} = FULL
Q = 10,300 CFS
POOL EL 723.7, TW EL 711.0



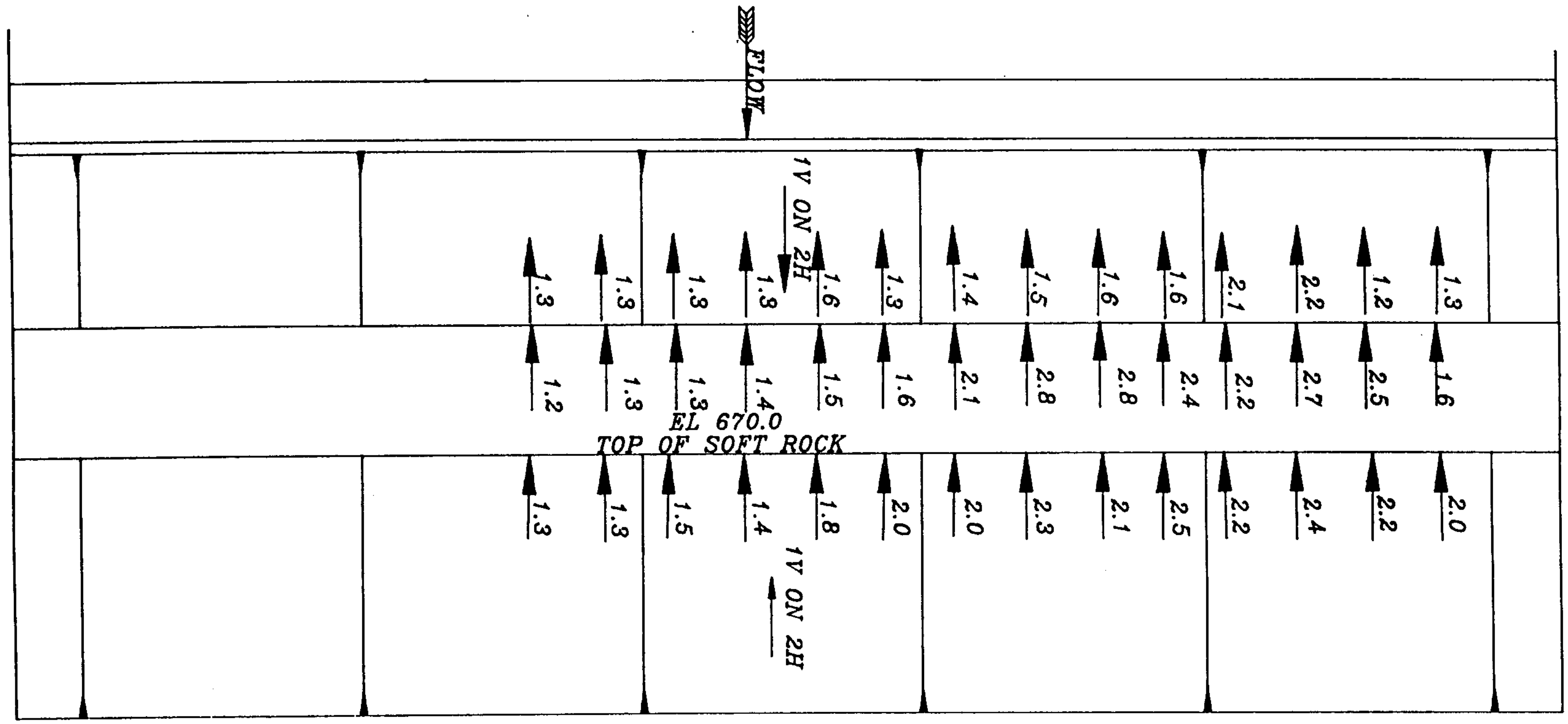
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION G RIPRAP
$G_L = 10$ FT
Q = 21,500 CFS
POOL EL 723.7, TW EL 710.0



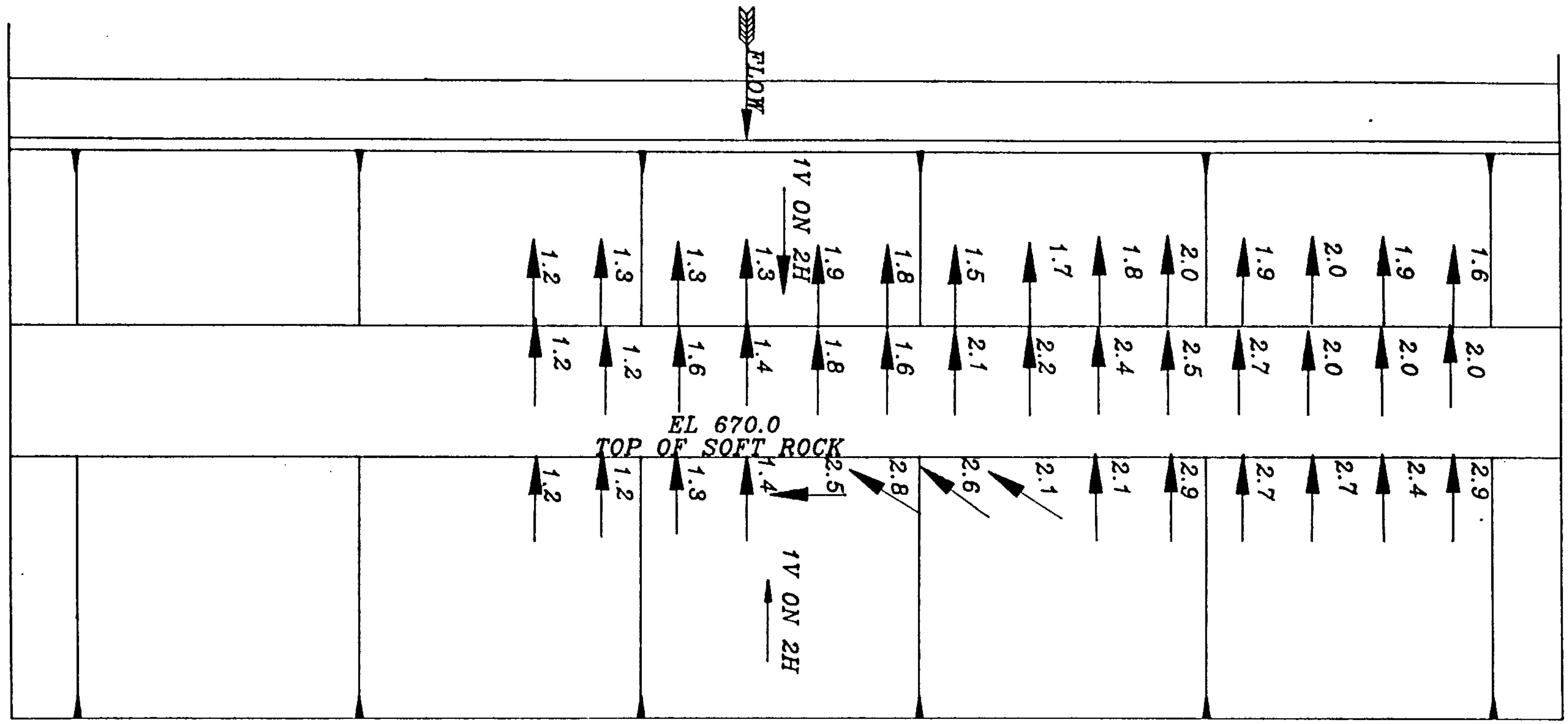
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION G RIPRAP
G_L = FULL
Q = 27,500 CFS
POOL EL 723.7 , TW EL 711.0



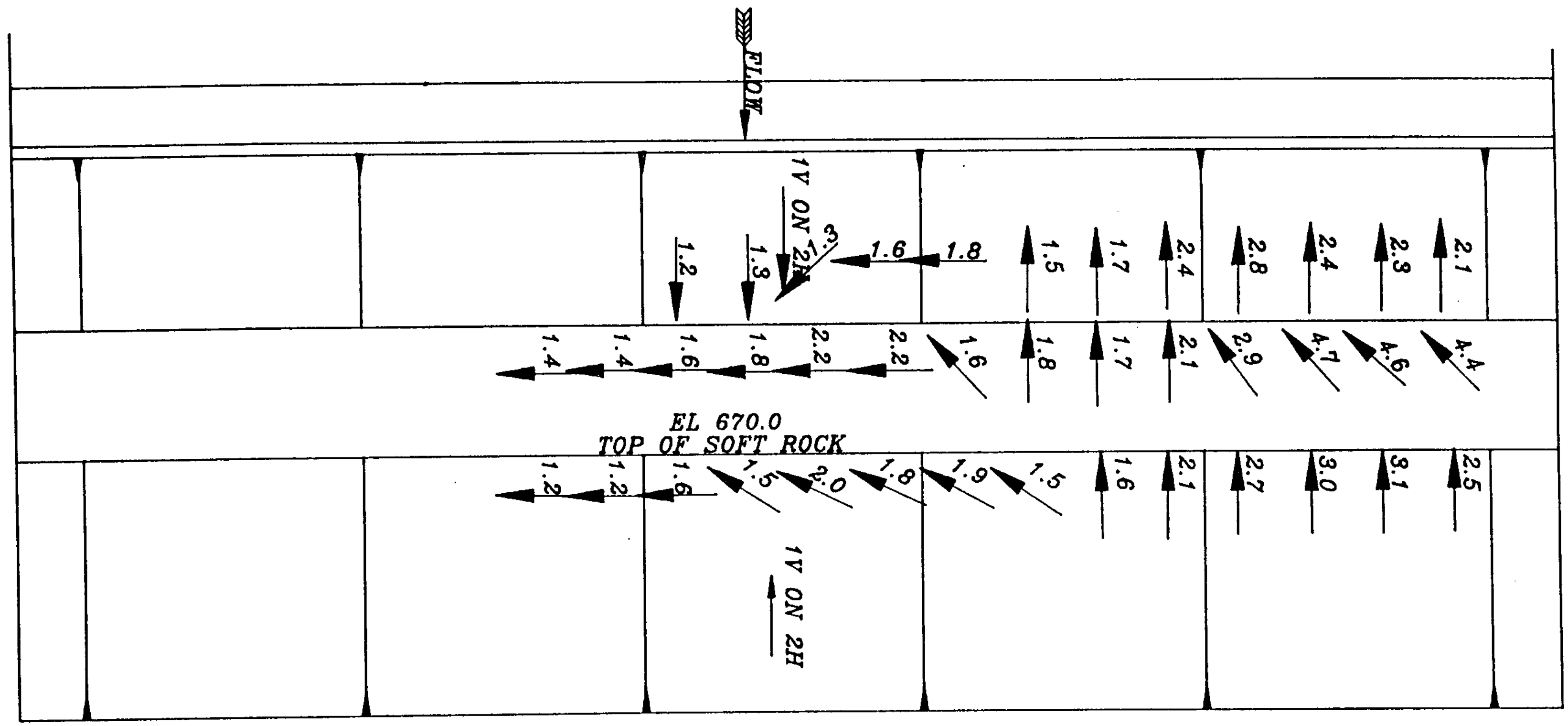
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION G RIPRAP
G_L = 10 FT, G_{wq} = FULL
Q = 31,000 CFS
POOL EL 723.7, TW EL 712.0



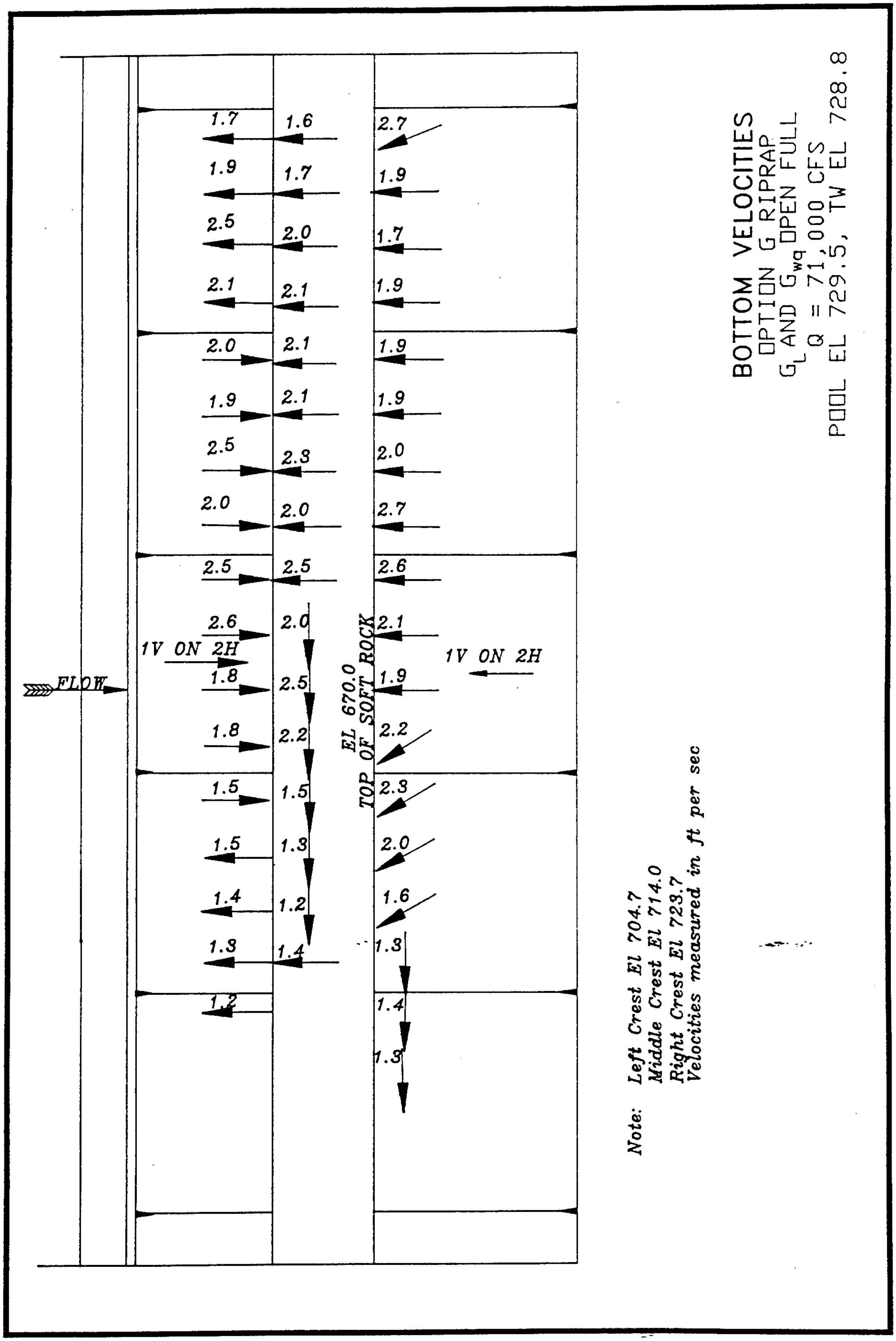
Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

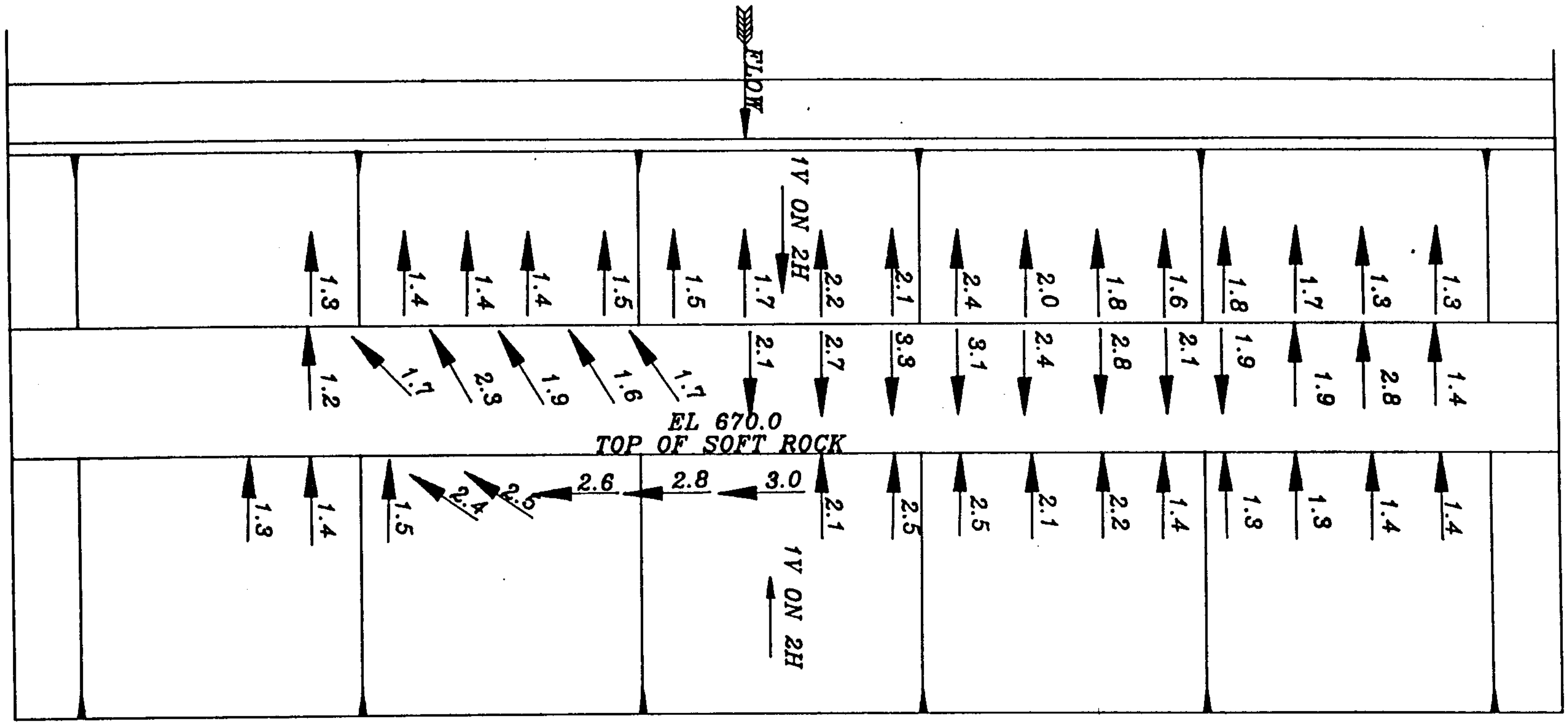
BOTTOM VELOCITIES
OPTION G RIPRAP
G_L AND G_{wq} OPEN FULL
Q = 36,0000 CFS
POOL EL 723.7, TW EL 720.2



Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

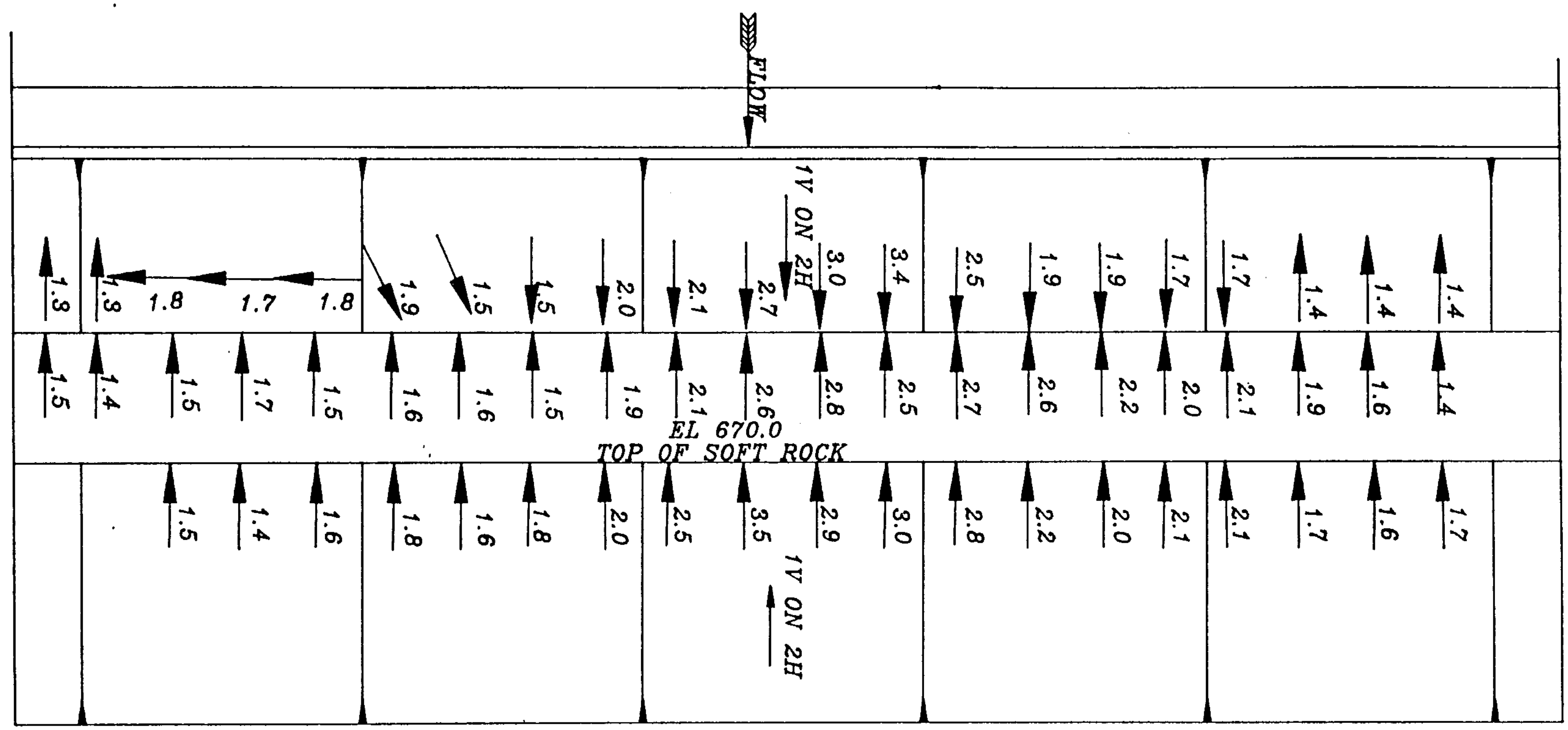
BOTTOM VELOCITIES
OPTION G RIPRAP
G_L AND G_{wq} OPEN FULL
Q = 36,500 CFS
POOL EL 723.7, TW EL 718.5


BOTTOM VELOCITIES
OPTION G RIPRAP
G_L AND G_{wq} OPEN FULL
Q = 71,000 CFS
POOL EL 729.5, TW EL 728.8
Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec
FLOW
1V ON 2H
1V ON 2H
EL 670.0
TOP OF SOFT ROCK
1.7
1.6
2.7
1.9
1.7
1.9
2.5
2.0
1.7
2.1
2.1
1.9
2.0
2.1
1.9
1.9
2.1
1.9
2.5
2.3
2.0
2.0
2.0
2.7
2.5
2.5
2.6
2.6
2.0
2.1
1.8
2.5
1.9
1.8
2.2
2.2
1.5
1.5
2.3
1.5
1.3
2.0
1.4
1.2
1.6
1.3
1.4
1.3
1.2
1.4
1.3



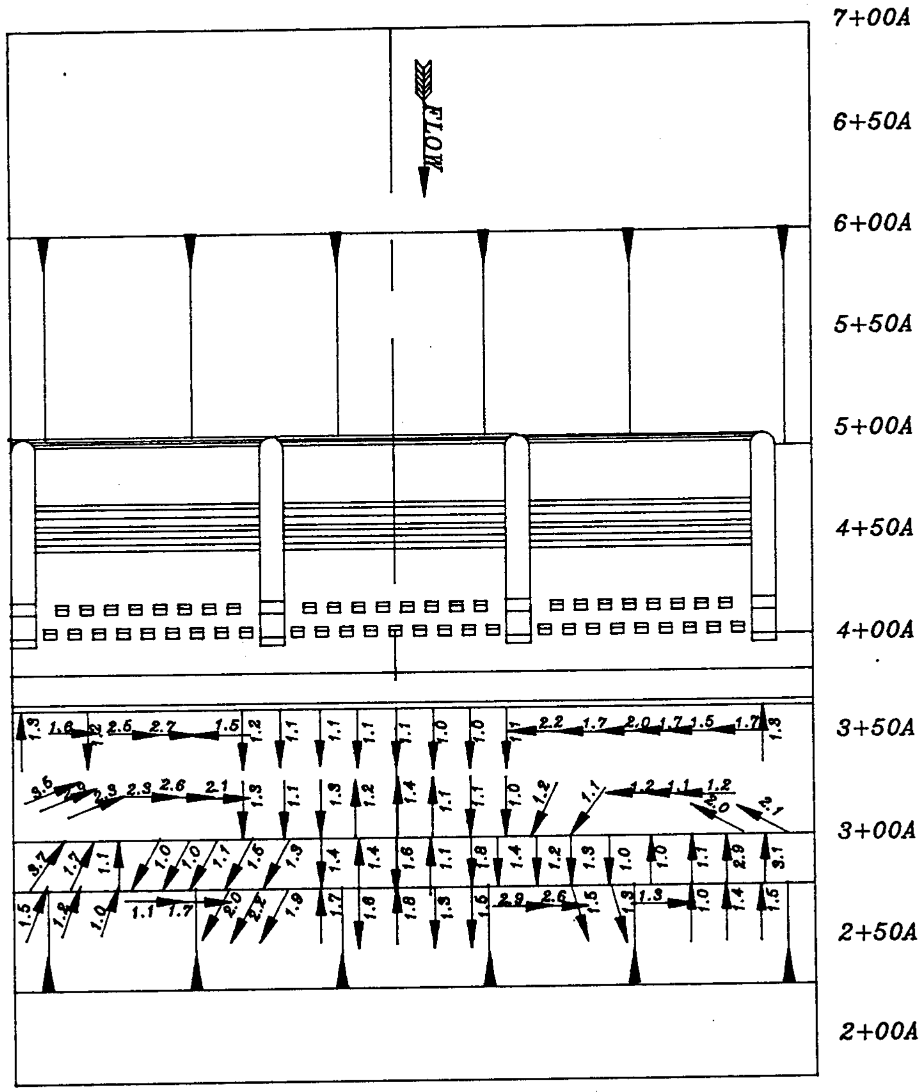
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION G RIPRAP
G_L AND G_{wq} OPEN FULL
Q = 86,500 CFS
POOL EL 734.0, TW EL 732.7



Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
Velocities measured in ft per sec

BOTTOM VELOCITIES
OPTION G RIPRAP
G_L AND G_{wq} OPEN FULL
Q = 104,000 CFS
POOL EL 739.6, TW EL 737.0



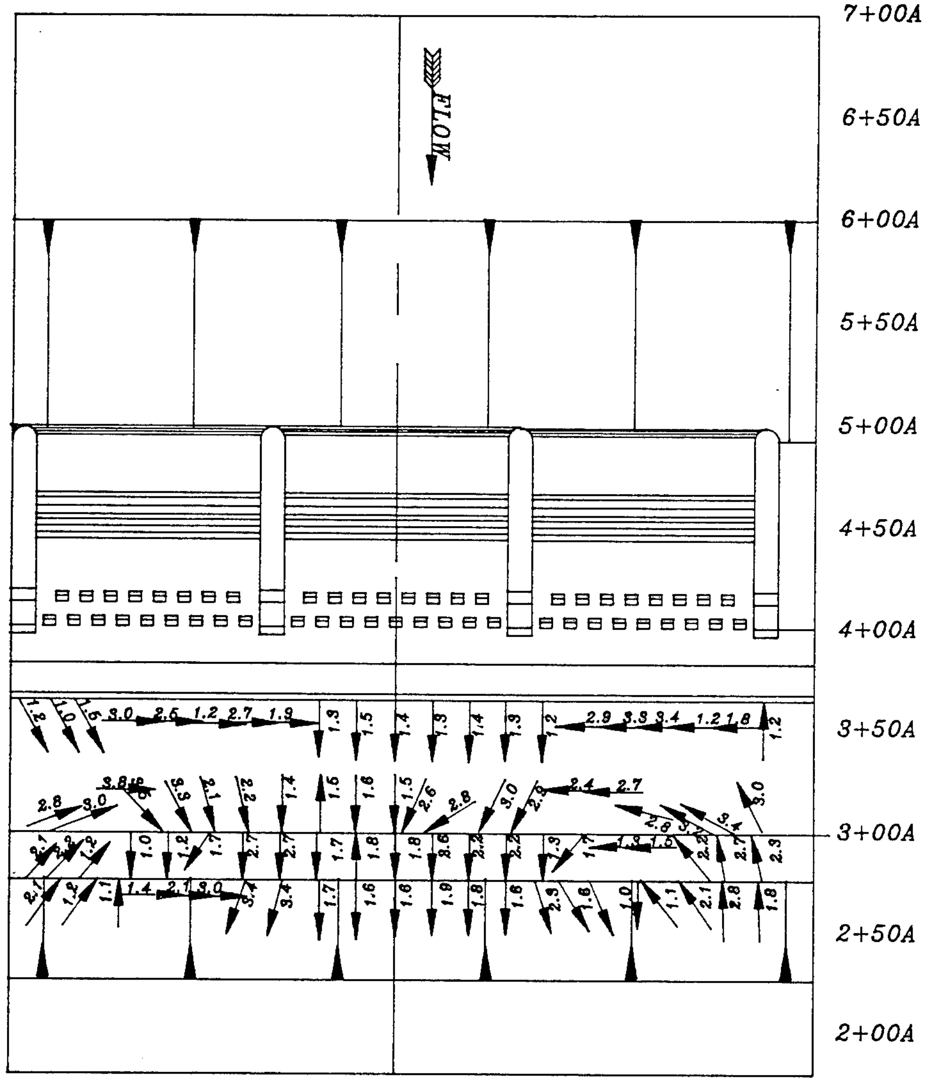
Note: Crest El 704.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES

G_M = 10 FT

Q = 21,500 CFS

POOL EL 723.7 , TW EL 710.0



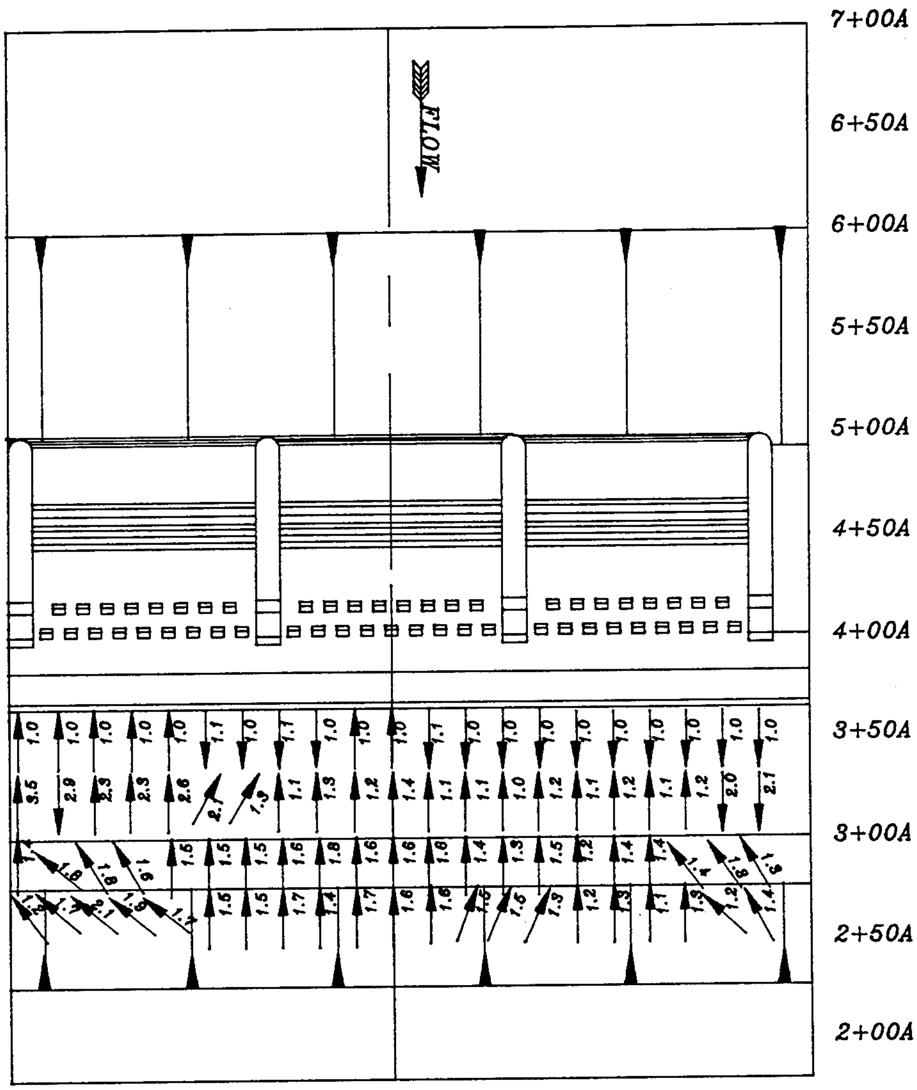
Note: Crest El 704.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES

G_M = FULL

Q = 27,000 CFS

POOL EL 723.7, TW EL 718.5



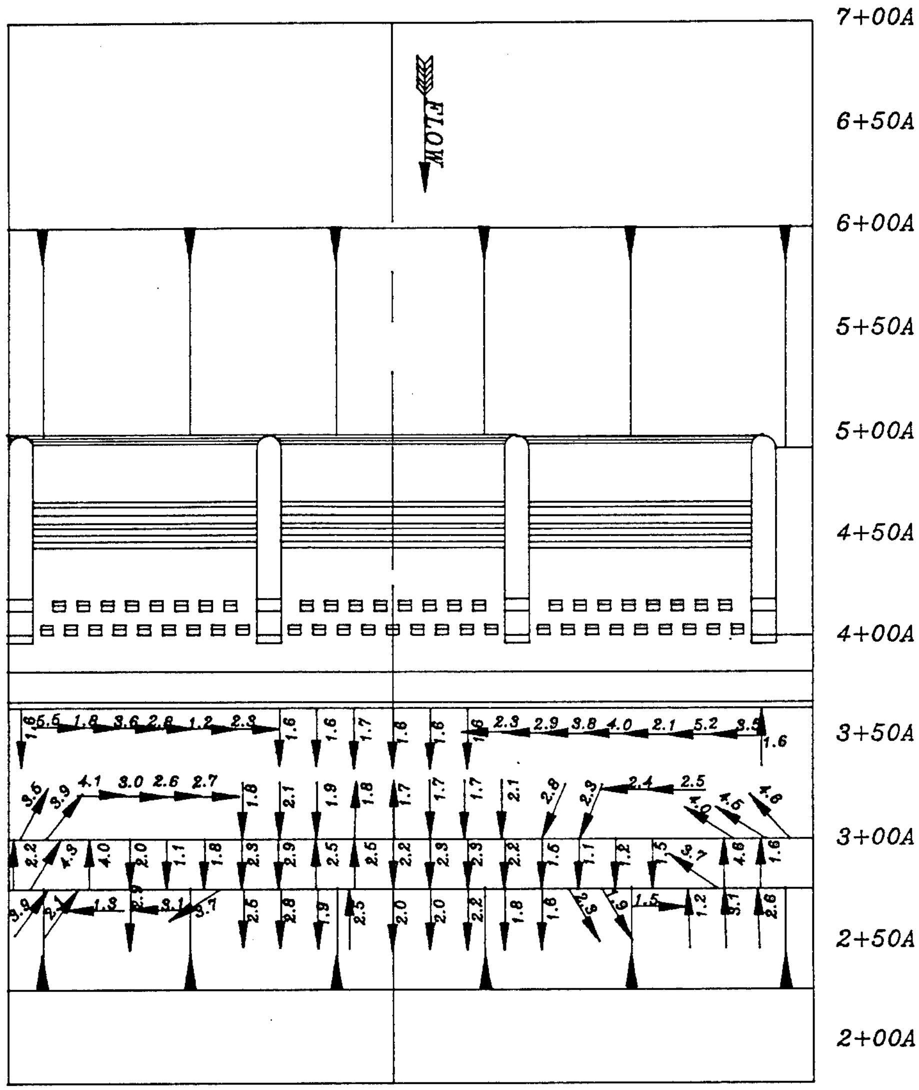
Note: Crest El 704.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES

G_L = 4 FT, G_M = 6 FT, G_R = 4 FT

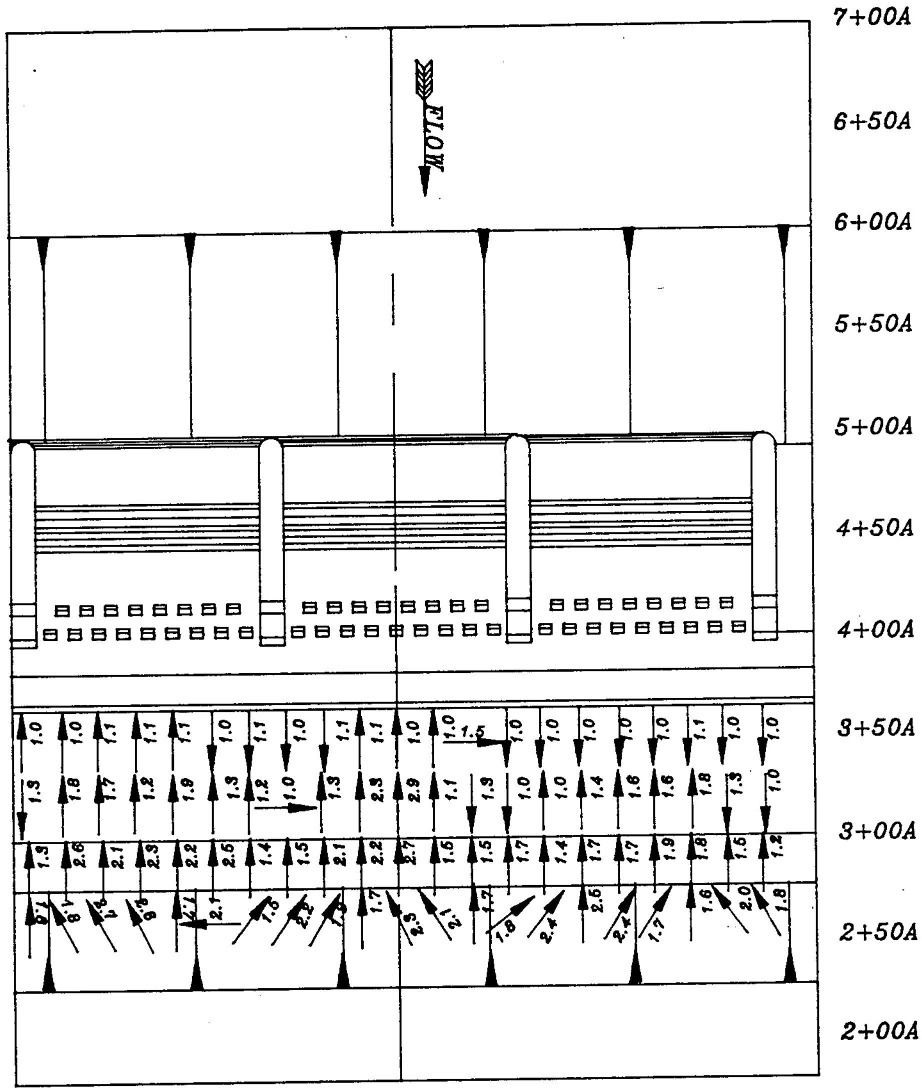
Q = 28,500 CFS

POOL EL 723.7, TW EL 714.5



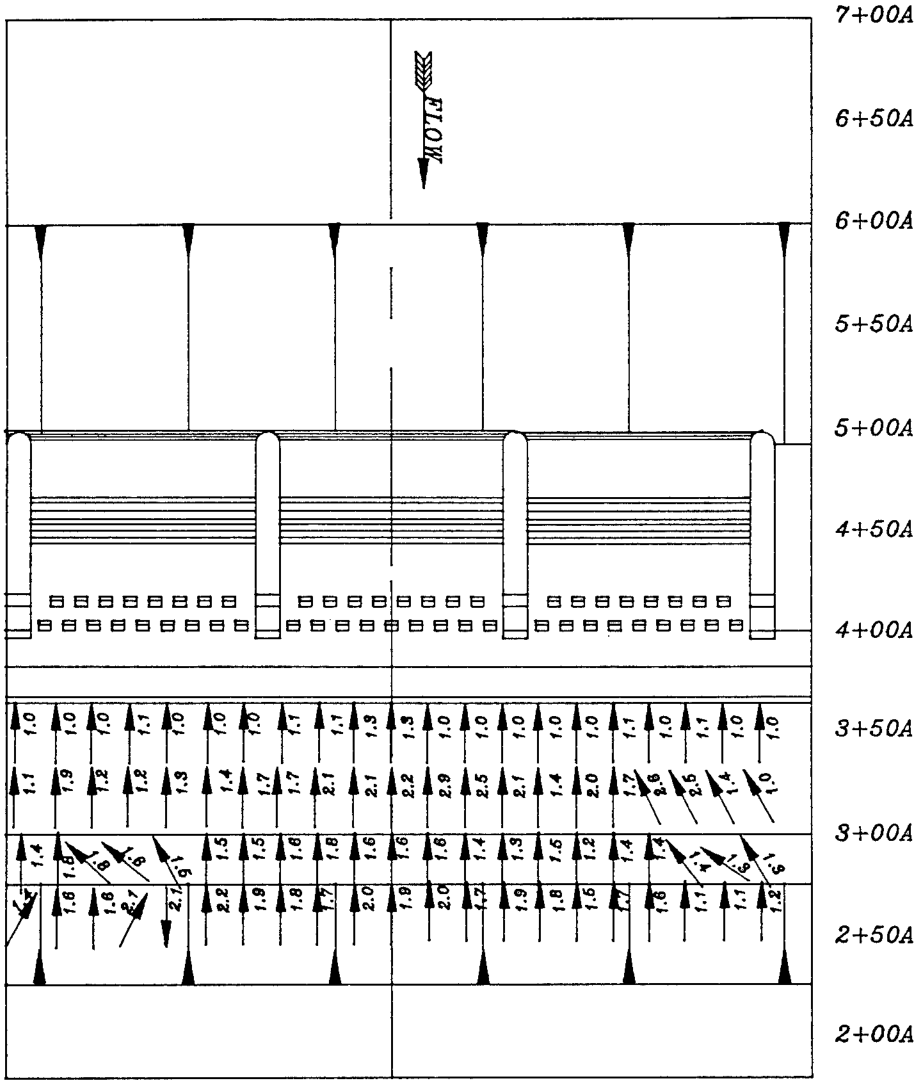
Note: Crest El 704.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES
G_M= FULL
Q = 27,500 CFS
POOL EL 723.7, TW EL 711.0



Note: Crest El 704.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES
ALL THREE GATES OPEN 8 FT
Q = 33,000 CFS
POOL EL 723.7, TW EL 720.0



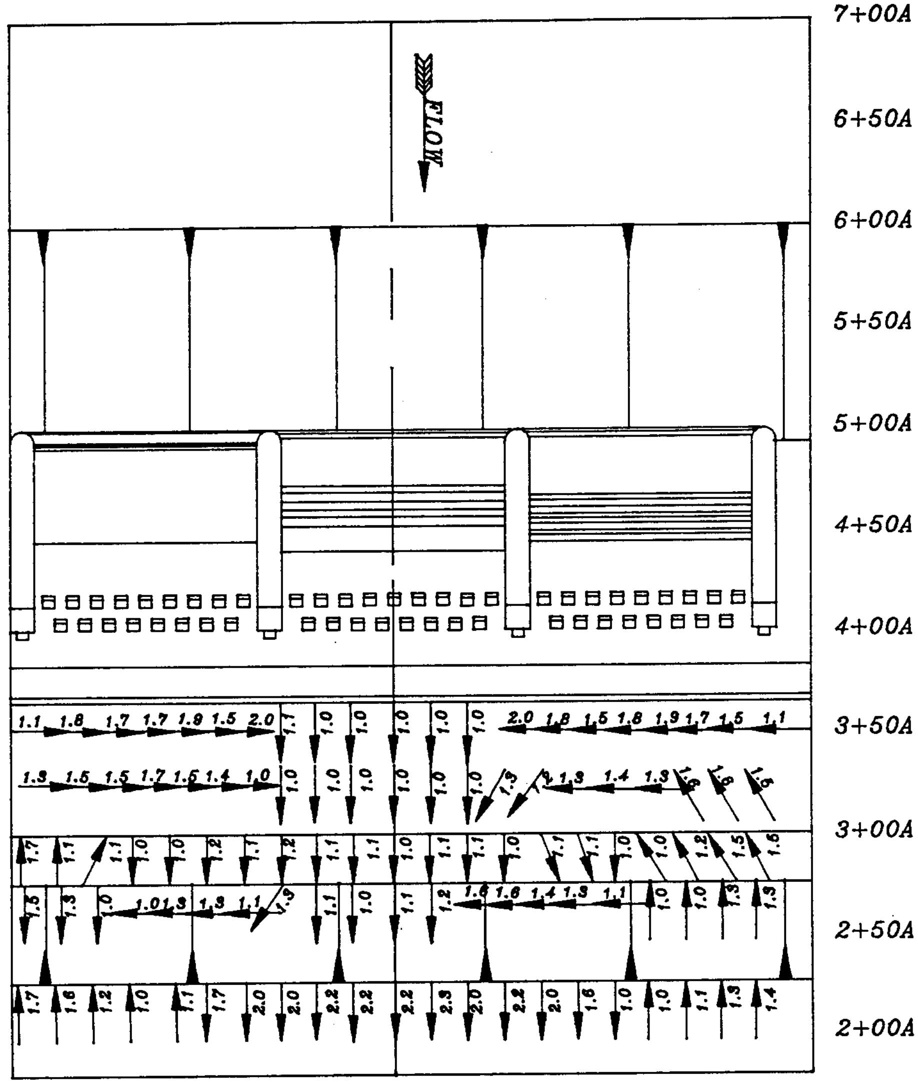
Note: Crest El 704.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES

G_L = 8 FT, G_M = 10 FT, G_R = 8 FT

Q = 48,000 CFS

POOL EL 723.7, TW EL 717.0



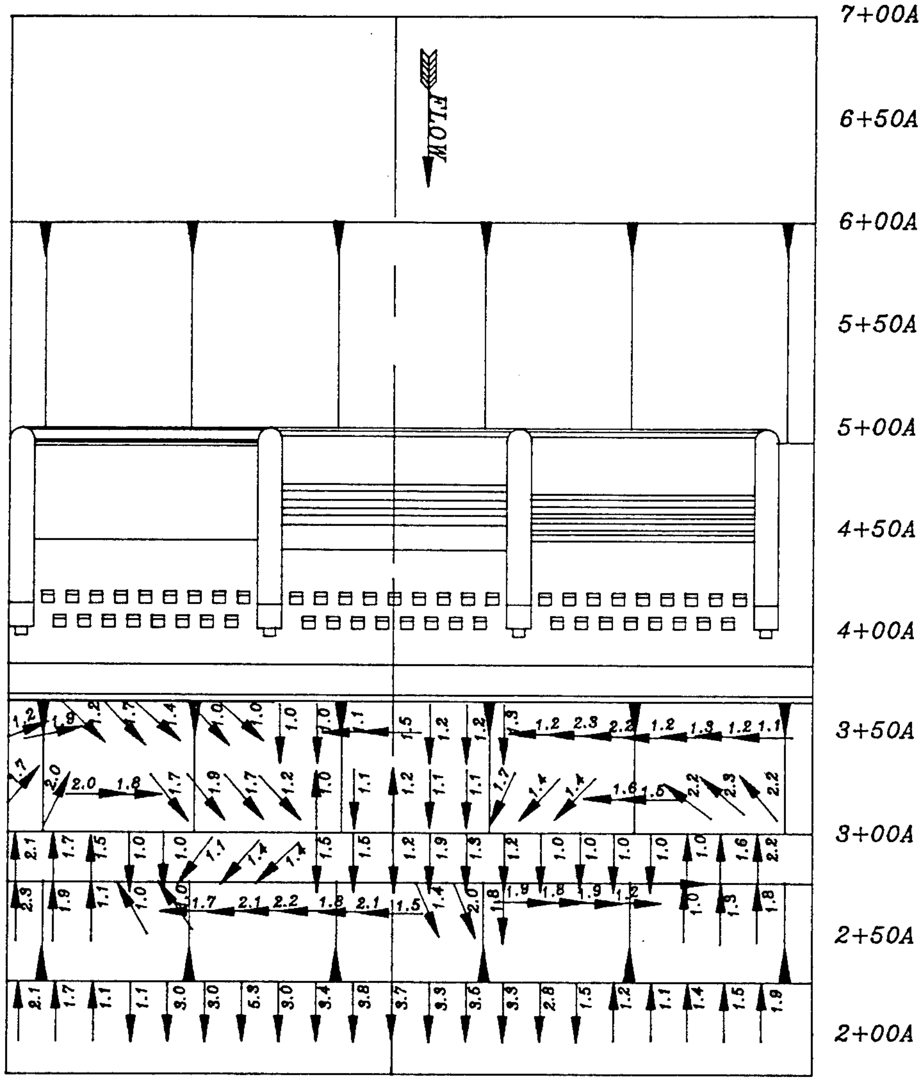
Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES

G_{wq} = 4 FT

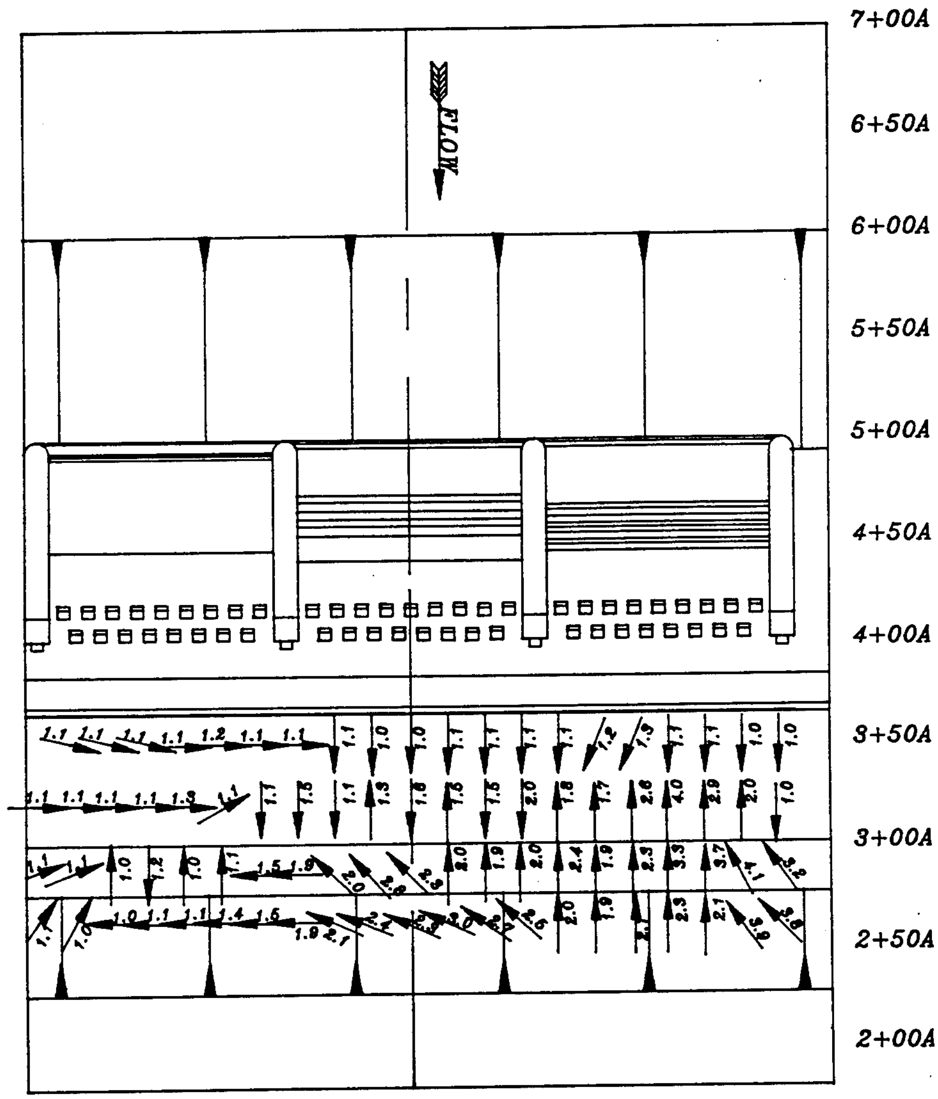
Q = 7,000 CFS

POOL EL 723.7, TW EL 710.5



Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES
G_{wq} = FULL
Q = 10,300 CFS
POOL EL 723.7, TW EL 711.0



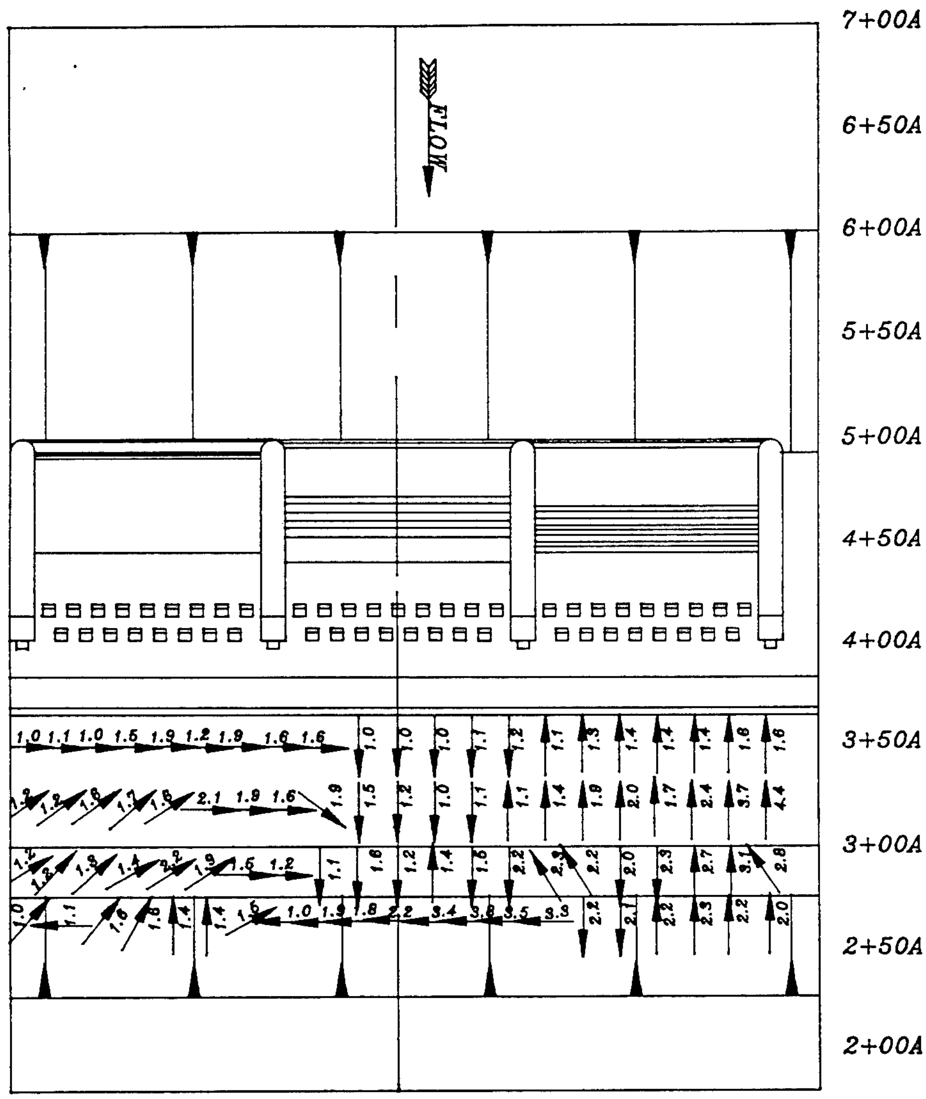
Note: ***Left Crest El 704.7***
Middle Crest El 714.0
Right Crest El 723.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES

G_L = 10 FT, G_{wq} = FULL

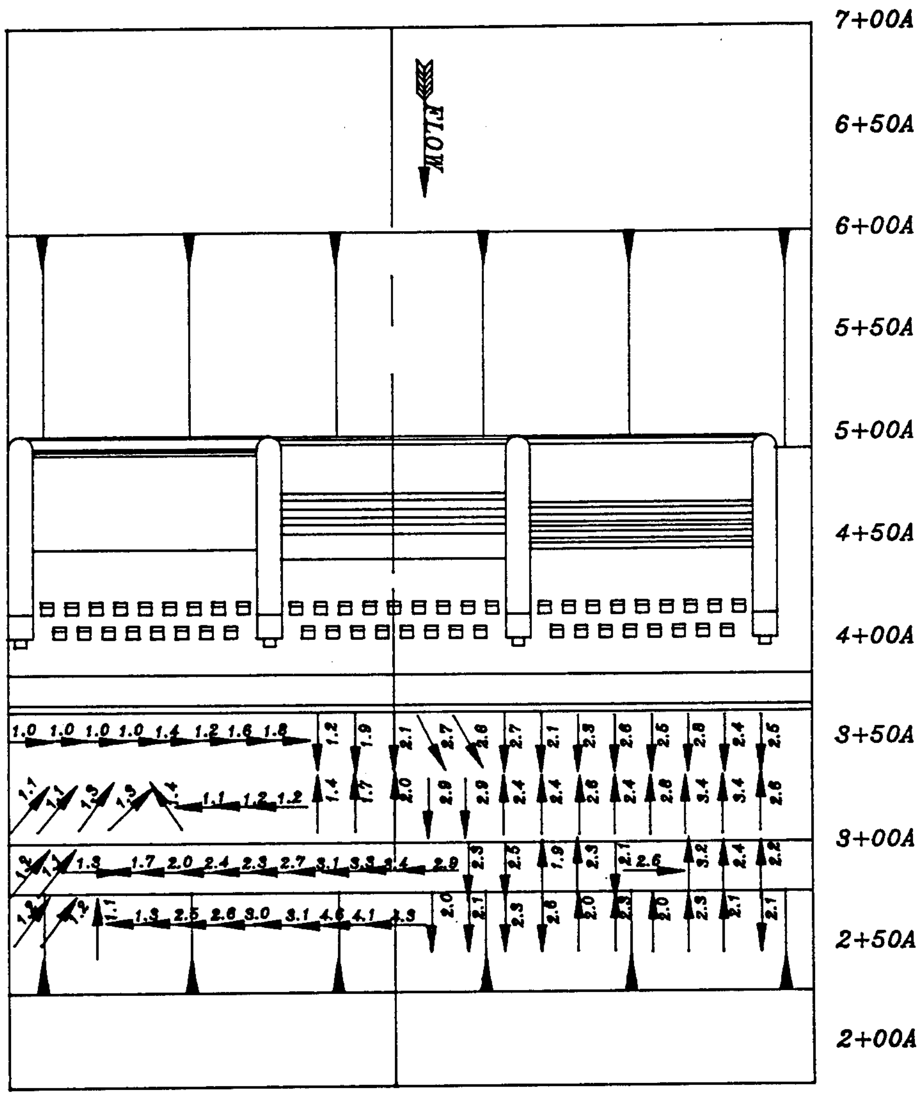
Q = 31,000 CFS

POOL EL 723.7, TW EL 712.0



Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES
G_L = FULL, G_{wq} = FULL
Q = 36,000 CFS
POOL EL 723.7, TW EL 720.2



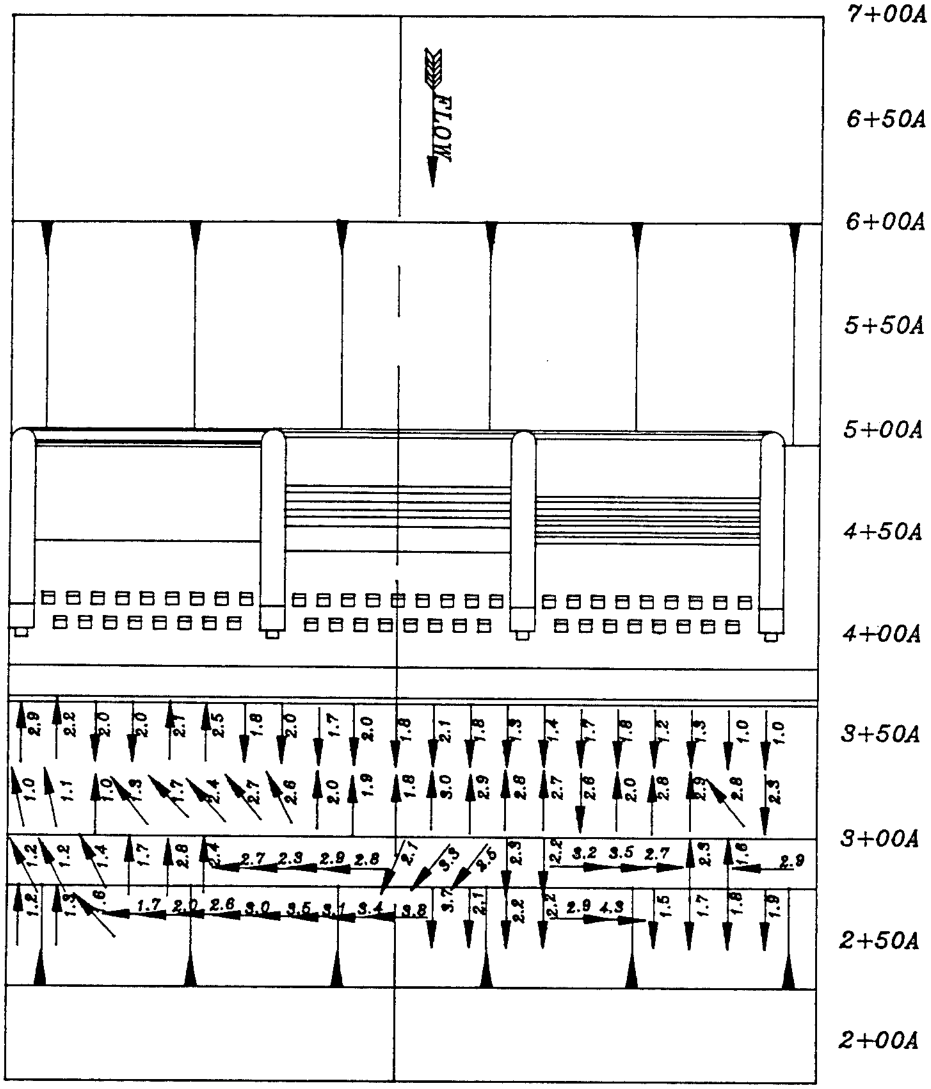
Note: *Left Crest El 704.7*
Middle Crest El 714.0
Right Crest El 723.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES

G_L = FULL, G_{wq} = FULL

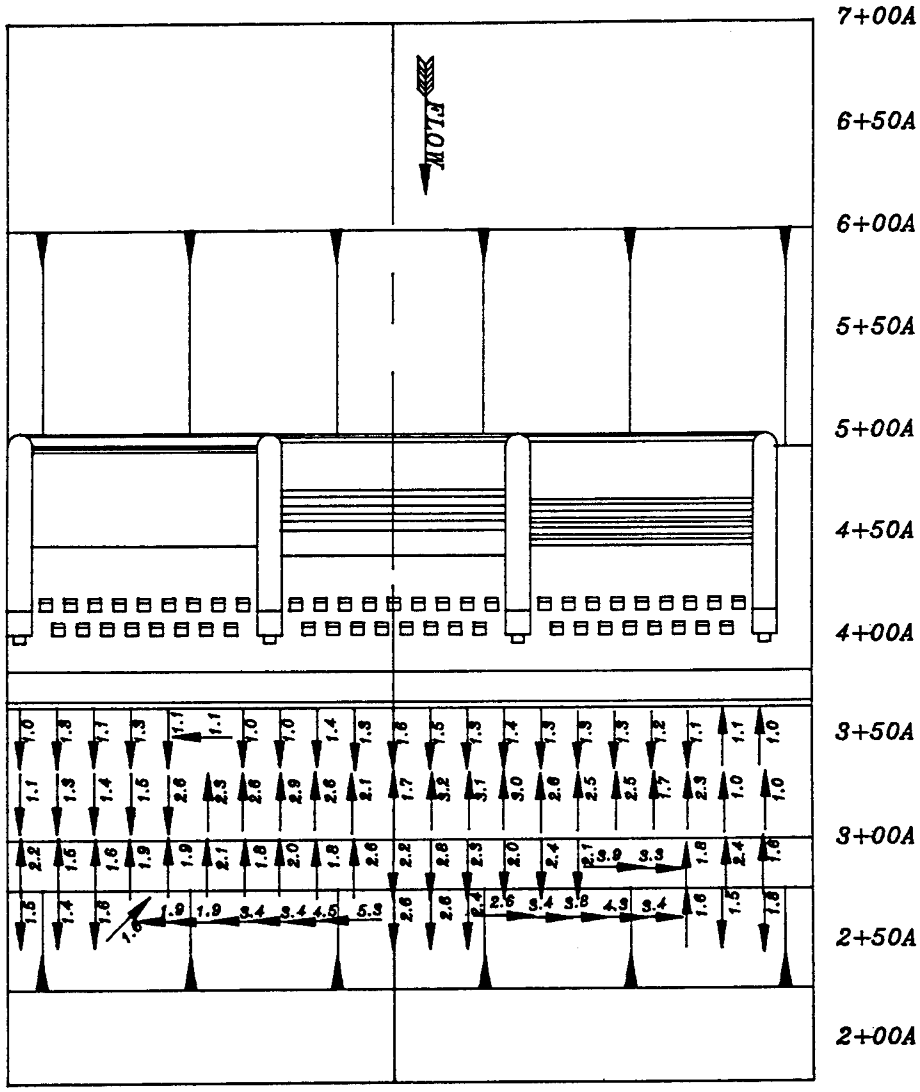
Q = 71,000 CFS

POOL EL 729.5, TW EL 728.8



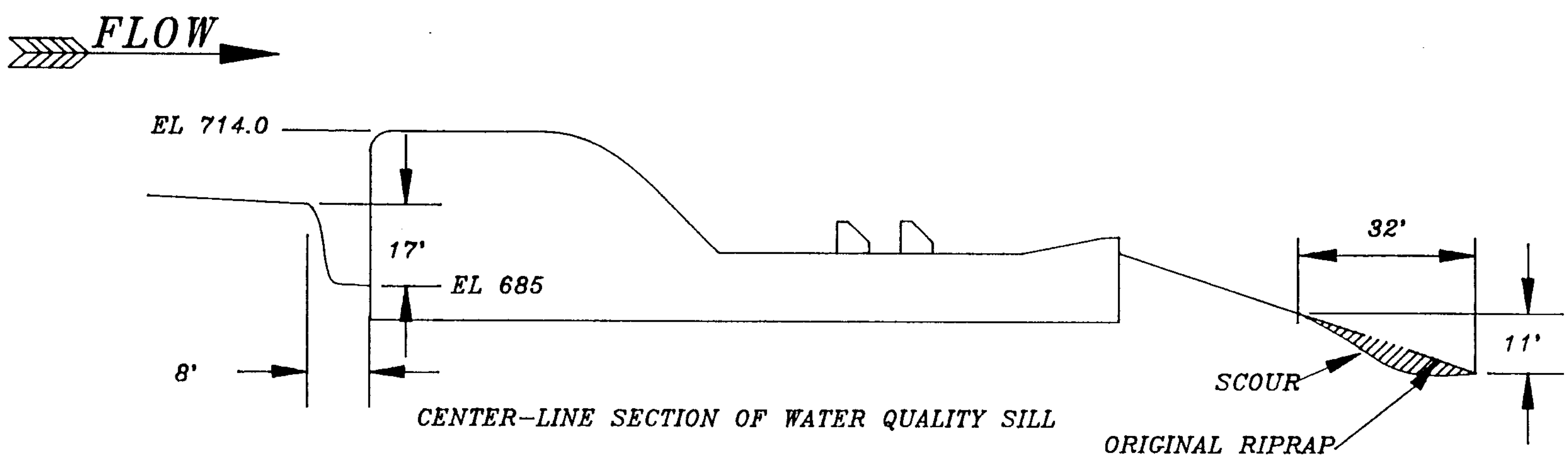
Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES
G_L = FULL, G_{wq} = FULL
Q = 86,500 CFS
POOL EL 733.4, TW EL 732.7

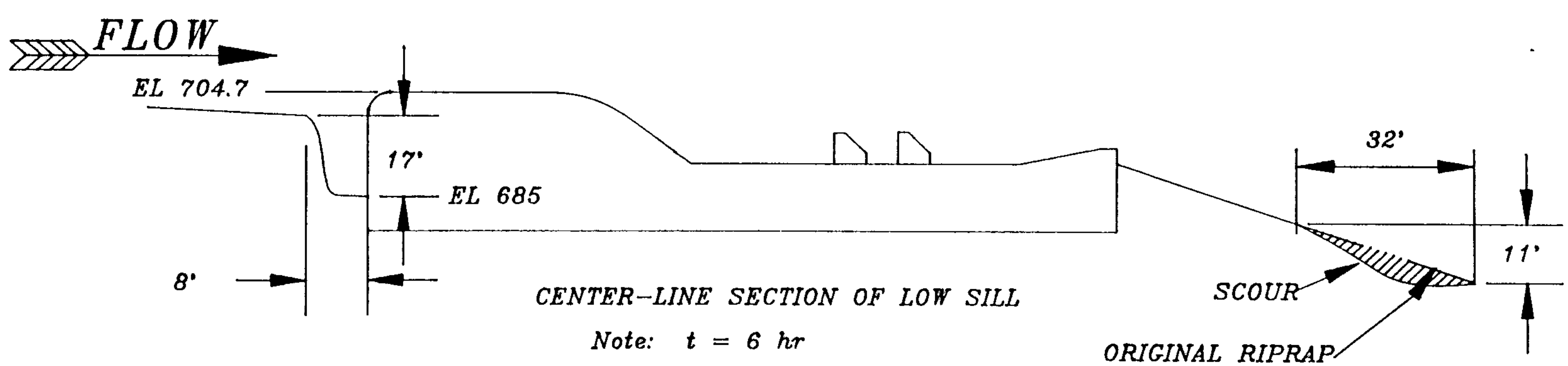


Note: Left Crest El 704.7
Middle Crest El 714.0
Right Crest El 723.7
No stone protection
Velocities measured in ft per sec

BOTTOM VELOCITIES
G_L = FULL, G_{wq} = FULL
Q = 104,000 CFS
POOL EL 739.6, TW EL 737.0



CENTER–LINE SECTION OF WATER QUALITY SILL



CENTER–LINE SECTION OF LOW SILL

Note: $t = 6$ hr

PROFILE VIEW OF SCOUR
G_L = OPEN FULL
Q = 77,000 CFS
HW EL 742.0, TW EL 721.0

Appendix A
Model Testing Schedule Provided by the Pittsburgh District

9 - 3
~~August __,~~ 1992
Leput/Povirk

LOCK & DAM #2 MONONGAHELA RIVER
NEW PROJECT CONDITIONS
PROPOSED SECTION MODEL TESTING
PERFORMANCE OF DAM, STILLING BASIN & DOWNSTREAM PROTECTION
BY CEORP-ED-HR
OPTION A & B STONE PROTECTION

TEST 1 Rate the small gate, large gate and weir for various tailwater conditions.

TEST 2

1 PROPOSED DAM (4 GATES), STILLING BASIN & STONE PROTECTION

2 PROPOSED DAM (4 GATES) & STILLING BASIN WITH MODIFIED STONE PROTECTION

GATE BAY PLAN

PLAN	BAY 1	BAY 2	BAY 3
1	C	LG½F*	C
2	C	LGF*	C
3	LGF	LGF	LGF
4	C	SGF	LGF
5	C	SGF**	C

C Bay closed
SGF Small gate full open with minimum tailwater for 4 gates open full
SGF** Small gate full open with tailwater at elevation 710 only
LGF Large gate full open with minimum tailwater for 4 gates open full
LGF* Large gate full open with tailwater at elevation 710
LG½F* Large gate ½ full open with tailwater at elevation 710
(14')

TEST 3 This test is the same as TEST 2 but for 5 gates & change in configuration.

TEST 4 Large and small gate ratings for final configuration.

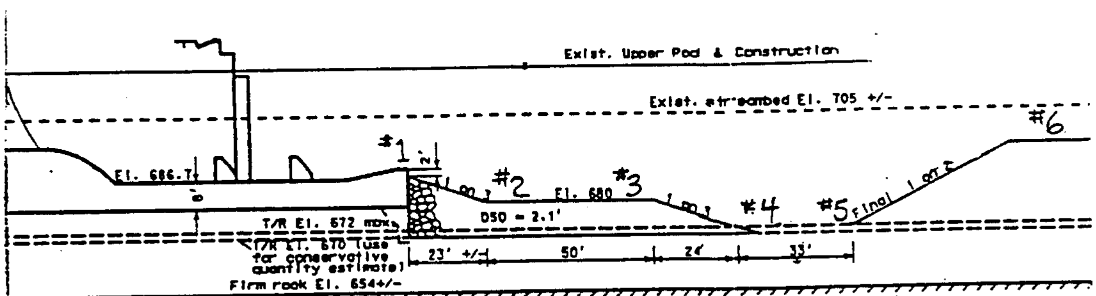
REV 3-1-93
REV 2-25-93
REV 2-19-93
2-17-93

OPTION C STONE PROTECTION
L/D #2 SECTION MODEL VELOCITY TESTING

TW	TOTAL Q	WATER QUAL GATE	IN MODEL LARGE GATE	IN MODEL LARGE GATE	IN MODEL LARGE GATE	LARGE GATE	MODEL Q
712	19500*	0	2	4	2	NA	19500
716	50500*	0	8	10	8	NA	50500
718.5	74500*	0	12	14	12	NA	74500
722.5	100000*	F(7)	F	F	F	NA	90000
718	31000$	F(7)	4	4	2	4	15000
720	66500$$	F(7)	10	10	8	10	41500
720.5	73000$$	F(7)	14	14	12	14	46000
730.8	168500*	F(7)	F	F	F	NA	130000
737.0	231500*	F(7)	F	F	F	NA	151000
~~740.0~~	~~275700*~~	~~F(7)~~	~~F~~	~~F~~	~~F~~	~~NA~~	~~167000~~

* MIN TAILWATER CURVE
$ MAX TAILWATER CURVE
$$ NORMAL TAILWATER CURVE
UPPER POOL IS 723.7 FOR ALL TESTS EXCEPT THE THREE HIGHEST FLOWS

#1-#6 ARE LOCATIONS OF NEEDED VELOCITY DATA FOR THE ABOVE TESTS



OPTION C - STONE WEDGE & BLANKET

WES IS TO GET VELOCITY DATA AS FAR AS NECESSARY LEFT-RIGHT OF CENTER GATE. FOR TESTS 5,6 & 7 (31000 - 73000) THEY ARE TO GET VELOCITIES TO THE RIGHT BOUNDARY OF THE MODEL

WES (COOPER) WILL DECIDE ON THE LEFT-RIGHT SPACING OF VELOCITY DATA

Povirk/Leput
CEORP-ED-HR

4-2-1993

PROPOSED L/D #2 SECTION MODEL SCOUR & VELOCITY TESTING
WITH SMALL (WQ) GATE SCHEME
OPTION C STONE PROTECTION

TEST	TAILWATER ELEV.	MODEL FLOW (CFS)	TOTAL FLOW (CFS)	UPPER POOL	WEIR	SMALL GATE	LARGE GATE
1	710*	3000%	3000%	723.7	NONE	2'	
2	713$	3000%	3000%	"	"	2'	
3	710.5*	6500	6500	"	"	4'	
4	713.5$	6500	6500	"	"	4'	
5	711*	10000	10000	"	"	(F)	
6	714$	10000	10000	"	"	(F)	
7	715*	42000	42000	"	"	(F)	14'
8	716*	53000	53000	"	"	(F)	(F)
9	730.8*	71000	168500	?	SOME	(F)	(F)

(F) GATE FULL OPEN AND CLEAR OF UPSTREAM POOL
* MIN TAILWATER CURVE
$ MAX TAILWATER CURVE
? MODEL WILL DETERMINE THIS ELEVATION
% APPROXIMATE FLOW MODEL WILL DETERMINE TRUE VALUE

TESTS 1-9 MODEL UTILIZED FOR STONE PROTECTION STABILITY & VELOCITY DATA

LEPUT/POVIRK
CEORP-ED-HR

DAM 2 SECTION MODEL, REVISED CONFIGURATION
SUGGESTED INITIAL TESTING TO EVALUATE
STILLING BASIN AND DOWNSTREAM RIPRAP
OPTION D STONE PROTECTION

TAIL WATER	UPPER POOL	TOTAL Q	W.Q. GATE	LARGE GATE	LARGE GATE	LARGE GATE	MODEL Q
711*	723.7	28,000	0	0	F	0	28,000
717$	723.7	28,000	0	0	F	0	28,000
721*	723.7	95,000	F	F	F	F	85,000
728.5*	730.8	150,500	F	F	F	F	115,000
710*	723.7	20,000	0	0	10'	0	20,000

*MIN TAILWATER
$MAX TAILWATER

R.P.
1/3/94

DAM 2 SECTION MODEL, REVISED CONFIGURATION
VELOCITY TESTS - THREE LARGE GATES
OPTION E STONE PROTECTION

TEST NO.	TAIL WATER	UPPER POOL	TOTAL Q	W.Q. GATE	LARGE GATE	LARGE GATE	LARGE GATE	MODEL Q
1	711*	723.7	27,500	0	0	F	0	27,500
2	718.5$	723.7	36,500	F	0	F	0	26,500
3	720.2*	723.7	85,000	F	F	F	F	75,000
4	728.8*	731.8±	150,500	F	F	F	F	111,000
5	710*	723.7	20,800	0	0	10′	0	20,800
6	714.5*	723.7	38,000	F	4′	6′	4′	28,000
7	717*	723.7	59,500	F	8′	10′	8′	49,500
8	720$	723.7	43,000	F	8′	8′	8′	33,000
9	737*	739.2±	231,500	F	F	F	F	137,000

Underlined tests to be run for "No Stone" Option as well
* MIN TAILWATER CURVE $ MAX TAILWATER CURVE

Derivation:

Test No.	Test Description	Q Locks/ esplanade	Q Lock-side weir	Q W.Q. Gate	Q Large Gates	Q Abut-side weir
1	Critical cond., operator error	0	0	0	1 @ 27,500	0
2	Critical cond., operator error	0	0	10,000	1 @ 26,500	0
3	Loss of pool	0	0	10,000	3 @ 25,000	0
4	5-Year flood	1000	7000	26,000	3 @ 37,000	5500
5	Debris passage	0	0	0	1 @ 20,800	0
6	Typical setting, rising river	0	0	10,000	2 @ 7900 (4′) 1 @ 12,200 (6′)	0
7	Typical setting, rising river	0	0	10,000	2 @ 15,000 (8′) 1 @ 19,500 (10′)	0
8	Typical setting, high tailwater	0	0	10,000	3 @ 11,000	0
9	100-Yr flood	20,000	20,000	36,000	3 @ 45,700	18,500

DAM 2 SECTION MODEL, REVISED CONFIGURATION
SMALL GATE INSTALLED IN CENTER BAY
VELOCITY TESTS - SMALL GATE (+ ONE LARGE GATE)
OPTION E STONE PROTECTION

TEST NO.	TAIL WATER	UPPER POOL	TOTAL Q	W.Q. GATE	LARGE GATE	LARGE GATE	LARGE GATE	MODEL Q
1	710.5*	723.7	6,500	4'	0	0	0	6,500
2	714$	723.7	6,500	4'	0	0	0	6,500
3	711*	723.7	10,000	F	0	0	0	10,000
4	714.5$	723.7	10,000	F	0	0	0	10,000
5	712*	723.7	30,800	F	10'	0	0	30,800
6	720.2*	723.7	85,000	F	F	F	F	35,000
7	728.8*	731.8±	150,500	F	F	F	F	63,000

Underlined tests to be run for "No Stone" Option as well

* MIN TAILWATER CURVE $ MAX TAILWATER CURVE

Derivation:

Test No.	Test Description	Q Locks/ esplanade	Q Lock- side weir	Q W.Q. Gate	Q Large Gates	Q Abut- side weir
1	Typical setting, rising river	0	0	6,500	0	0
2	Typical setting, high tailwater	0	0	6,500	0	0
3	Max opening, rising river	0	0	10,000	0	0
4	Max opening, high tailwater	0	0	10,000	0	0
5	Debris passage	0	0	10,000	1 @ 20,800 (10')	0
6	Loss of pool	0	0	10,000	3 @ 25,000 (F)	0
7	5-Year flood	1000	7000	26,000	3 @ 37,000 (F)	0

Rev. R.P. 7/27/94

DAM 2 SECTION MODEL, REVISED CONFIGURATION
LARGE GATE INSTALLED IN LEFT BAY
SMALL GATE INSTALLED IN CENTER BAY
FIXED WEIR INSTALLED IN RIGHT BAY
D.S. RIPRAP STONE SIZE INCREASED
(OPTION F - D50 = 2.1 FT, TOE STONE D = 2.5 TO 3.2 FT)
VELOCITY & RIPRAP STABILITY TESTS

TEST NO.♠	TAIL WATER	UPPER POOL	TOTAL Q	WEIR	W.Q. GATE	LARGE GATE	LARGE GATE	LARGE GATE	MODEL Q
<u>6</u>	720.2*	723.7	85,000	U	F	F	F	F	35,000
<u>7</u>	728.8*	731.6±	150,500	U	F	F	F	F	71,000
<u>8</u>	732.7*	735.1±	186,000	U	F	F	F	F	86,500
<u>9</u>	737.0*	739.0±	231,500	U	F	F	F	F	104,000
10 ¶	721.0	740.5±	77,000	B	B	F	B	B	77,000

<u>Underlined tests to be run for "No Stone" Option as well</u>
♠ TESTS 1-5 OF 5/24/94 SCHEDULE NEED NOT BE RERUN
* MIN TAILWATER CURVE
¶ NO VELOCITIES MEASUREMENTS REQUIRED FOR TEST 10
U = UNCONTROLLED
F = OPEN FULL
B = BLOCKED

Derivation:

Test No.	Test Description	Q Locks+ esp+abut	♦ Q Lock-side weir	Q W.Q. Gate	Q Large Gates	Q Abut-side weir
6	Loss of pool	0	0	10,000	3 @ 25,000 (F)	0
7	5-Yr flow	1,000	7,000(p) 8,000(m)	25,500	3 @ 37,500 (F)	5,000
8	20-Yr flow	8,000	12,000(p) 14,000(m)	31,000	3 @ 41,500 (F)	10,500
9	100-Yr flow	20,000	20,000(p) 23,000(m)	34,500	3 @ 46,500 (F)	18,000
10	Barge jam	0	0	0	1 @ 77,000 (F)	0

♦ Prototype (p) weir length = 93.83 ft
Model (m) weir length = 110 ft

Rev. R.P. 7/27/94

DAM 2 SECTION MODEL, OPTION G STONE PROTECTION
LARGE GATE IN LEFT BAY, W.Q. GATE IN CENTER BAY, FIXED WEIR IN RT. BAY
STONE D = 2.5 TO 3.2 FT
VELOCITY & RIPRAP STABILITY TESTS

R.P. 1/9/95

TEST NO.♠	TAIL WATER	UPPER POOL	TOTAL Q	WEIR	W.Q. GATE	LARGE GATE	LARGE GATE	LARGE GATE	MODEL Q
1	711.0*	723.7	27,500	-	0	F	0	0	27,500
2	718.5$	723.7	36,500	-	F	F	0	0	36,500
3	710.0*	723.7	21,000	-	0	10′	0	0	21,000
4	712.0*	723.7	31,000	-	F	10′	0	0	31,000
5	710.5*	723.7	6,500	-	4′	0	0	0	6,500
6	711.0*	723.7	10,000	-	F	0	0	0	10,000
7	720.2*	723.7	85,000	-	F	F	F	F	35,000
8	728.8*	731.6±	150,500	U	F	F	F	F	71,000
9	732.7*	735.1±	186,000	U	F	F	F	F	86,500
10	737.0*	739.0±	231,500	U	F	F	F	F	104,000

* MIN TAILWTR CURVE $ MAX TAILWTR CURVE   U=UNCONTROLLED   F=OPN FULL

<u>Derivation:</u>

Test No.	Test Description	Q Locks+ esp+abut	♦ Q Lock-side weir	Q W.Q. Gate	Q Large Gates	Q Abut side weir
1	Operator error	0	0	0	1 @ 27,500	0
2	Operator error	0	0	10,000	1 @ 26,500	0
3	Debris passage	0	0	0	1 @ 21,000	0
4	Debris passage	0	0	10,000	1 @ 21,000	0
5	Typical setting	0	0	6,500	0	0
6	Max opening	0	0	10,000	0	0
7	Loss of pool	0	0	10,000	3 @ 25,000 (F)	0
8	5-Yr flow	1,000	7,000(p) 8,000(m)	25,500	3 @ 37,500 (F)	5,000
9	20-Yr flow	8,000	12,000(p) 14,000(m)	31,000	3 @ 41,500 (F)	10,500
10	100-Yr flow	20,000	20,000(p) 23,000(m)	34,500	3 @ 46,500 (F)	18,000

♦ Prototype (p) weir length = 93.83 ft, Model (m) weir length = 110 ft

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13. ABSTRACT *(Maximum 200 words)*

Monongahela Dam 2, located 11.2 miles upstream of the confluence of the Ohio, Allegheny, and Monongahela Rivers, in North Braddock, PA, maintains the 12.6-mile-long navigation pool between the Dam 2 and Dam 3 locks and dams. The U.S. Army Engineer District, Pittsburgh, developed a "two-for-three" plan for renovating locks and dams on the lower Monongahela River that would save the cost of having to reconstruct Lock and Dam (L&D) 3 and reduce transportation costs by eliminating bottlenecks caused by the small locks at L&D's 3 and 4 and by reducing one lockage cycle. The plan calls for building a new gated dam at the current L&D 2, eliminating L&D 3, and replacing the locks at L&D 4 with new, larger locks. The change would also mean Pool 2 would be raised by about 5 ft, and the current Pool 3 would be lowered by about 3 ft. The dam now proposed for the L&D 2 site will consist of a navigable gated structure with three low sills (crest el 704.7), a water quality sill (crest el 714.0), and a fixed-crest weir (crest el 723.7). (All elevations (el) are given in feet referred to the National Geodetic Vertical Datum.) The spillway sectional model was conducted to investigate the hydraulic performance to be expected with the low sills and water quality sill under long-range operating conditions for controlled and uncontrolled flows. The model study provided the data necessary to evaluate and develop a satisfactory means of regulating the structure to achieve the desired flow objectives without creating adverse hydraulic conditions.

14. SUBJECT TERMS

Broad-crested sills	Ice passage	Tainter gates
Discharge coefficients	Riprap	Velocities
Energy dissipation	Scour	Water quality sills
Fixed crest	Stilling basin	Weir

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